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TECHNICAL REPORT
NADC-79186-60

AUTOMATIC LIFE RAFT DEPLOYMENT SYSTEM

FOR THE CH-46 HELICOPTER

M. J. Reilly
Boeing Vertol Company
Philadelphia, Pa. 19142

JULY 1981

FINAL REPORT FOR PERIOD SEPTEMBER 1979 - JULY 1981

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NAVAL AIR DEVELOPMENT CENTER

Warminster, Pennsylvania

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Helicopters are subject to roll-over and sinking within a minute of being forced down in sea states of 2 or greater. Internally stowed life rafts are virtually impossible to carry to escape hatches and deploy while water rushes in and the aircraft rolls or pitches in waves. Boeing was awarded a contract by NADC to develop an externally mounted raft container pod with automatic and manual deployment initiation system. Container pod and controls were designed and fabricated for externally mounting the life raft. Demonstration tests were successfully conducted using various modes of initiation.

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SUMMARY

Preface

This document was prepared for the Aircraft and Crew Systems Technology Directorate (60) of the Naval Air Development Center (NAVAIRDEVCEN), Warminster, Pennsylvania, by the Boeing Vertol Company under Contract N62269-79-C-0723. The contract period was from September 1979 through July 1981. The purpose of this contract was to design, fabricate, and demonstrate one (1), automatic, life raft deployment system for the H-46 helicopter which will provide an available raft for crew evacuating a sinking helicopter.

The project is part of a more comprehensive Navy program "Helicopter Aircrew Survivability Enhancement Program" (HASEP) whose objective is the integration of newly developed safety systems into currently operational helicopters. Included in the safety systems are crashworthy troop seating, emergency flotation, crashworthy cargo restraint and automatically deployed life rafts. This project is limited to the development of an automatically deployed life raft.

This effort focused on the problems of providing a readily available inflated life raft accessible to the main escape hatches of the CH-46 helicopter when forced down on the water and sinking or capsized. Minimum weight, automatic and rapid deployment and system reliability are crucial factors considered.

The author gratefully acknowledges the counsel and deep involvement of the NADC Project Technical Monitors, Mr. Joseph Micciche and William Wiesemann who contributed significantly to the program during the design and demonstration phases.

Introduction

The H-46 helicopter was designed to operate on water and remain afloat in wave heights up to 2 feet with the rotors shut down. Water integrity depends on all hatches and the ramp being closed prior to landing. Water landing capability has been demonstrated in flight test of the pilots operating manual envelope of 480 ft./min. rate of descent at touchdown speed of 20 knots or 240 ft./min. at 30 knots. Historically, H-46 helicopters have made emergency and uncontrolled landings with hatches open and/or exceeding the flight envelope. The emergency landings have occurred because of power failures, mechanical failures, pilot disorientation at night and other uncontrolled factors. In these cases the aircraft usually rolls over inverted, fills with water and sinks within 1 to 2 minutes. Movement of stowed life rafts to the escape hatches and inflating them outside is virtually impossible with water rushing through the hatch or while the aircraft is rolling over or is inverted in the water.

The purpose of this contract is to remedy this situation by developing an externally stowed life raft which will be automatically deployed and inflated without action by the crew during ditching.

The initial phase included design of a control valve which opens the CO_2 cylinder for raft inflation by either an electrically operated squib or by manually pulling a cable. An externally mounted, cylindrical, plastic container pod was designed to be quickly installed or removed on the aircraft for missions requiring extended over water flight. The pod is attached to hard points on the aircraft with 4 bolts. Systems remaining in the aircraft after pod removal include electrical control panel, wiring, water sensor and hard point structure and weighs approximately 5 pounds. The pod

was designed to split in half and jettison its spherical end caps for raft deployment. A frangible hinge provided pod integrity until pressure in the inflating raft shears the hinge pin at 3 inch segments.

A test fixture, simulating the CH-46 contour at the pod installation points, was fabricated. A container pod was molded of thermo-plastic material and installed on the test fixture. The life raft manual CO_2 control valve was replaced with a new remote/manual control valve. Several demonstrations of the complete system were performed which tested the control valve operation in the remote and manual modes, the frangible pod opening device, the integrity of the pod system, the automatic water sensing initiation system and raft deployment.

Conclusions

All design features of the life raft deployment system were proven. Automatic initiation of the system using the water pressure sensor functoned properly, causing the squib to fire and the CO_2 cylinder to discharge into the raft. The control valve mechanism functioned properly opening the CO_2 valve, whether driven by the squib or manually operated by the pull cable. Pod integrity was proven as the raft pressure increased causing the pod hinge pin to shear and the pod to open. The raft deployed properly in each of the 3 deployments conducted.

Recommendations

As a result of the tests reported herein the automatic life raft system is sufficiently qualified to consider installation on the CH-46 aircraft or other helicopters in the Navy inventory.

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Background

When a helicopter enters water due to an emergency or impacts water inadvertently, two major causes of casualties to the occupants arise. First, helicopters enter the water and sink, often rapidly, in less than one minute. Second, because helicopters have a high center of gravity, they are unstable in water. This instability can cause instant rollover, making egress difficult or impossible.

Numerous problems confront would-be survivors in their efforts to egress successfully from sinking, capsizing helicopters. They must contend with shifting displaced cargo and equipment inside the cabin. They must cope with disorientation, confusion, and panic as the helicopter impacts, fills with water, capsizes and sinks. They must release restraining straps, and locate, release, and deploy internally stowed life rafts. And through it all they must contend with inrushing water.

U. S. Navy and Marine Corps helicopter crewmen and passengers have faced these problems on many occasions, and survivors have repeatedly stressed the need for some method of reducing the criticality of these challenges and improving the survivability odds.

Objective

The objective of this program is to develop the best method of modifying, or adding to, a helicopter airframe so that an externally mounted, automatically inflated, self-deployable, multiplace life raft could be used for human survival. This objective will be accomplished by analyzing the physical and functional compatibility requirements of the airframe, designing an appropriate life raft deployment system and conducting demonstrations.

In order to effectively study the survivability problem, a single type of helicopter with a documented history of water ditching and inadvertent water entry mishaps was selected.

The CH-46 helicopter was selected from the Navy's inventory as the most logical candidate to be studied to demonstrate the technology of adding to or modifying the airframe to accept this type of survival system. The selection of the CH-46 helicopter to determine the feasibility of such a proposed survivability system was based on the following:

It is in widespread use by both the U. S. Navy and Marine Corps.

It carries relatively large numbers of combat troops who are usually insufficiently trained in water escape and survival, and usually wear minimum flotation devices while on board.

The relatively large size of the CH-46 makes it amenable to airframe additions and modifications required to accommodate the envisioned system.

SCOPE

An automatic, 12 man life raft deployment system shall be designed and integrated with the CH-46 aircraft determining interface with existing structure and modifications necessary to that structure. A prototype system shall be designed, tested and demonstrated. This technical effort shall be performed in two major tasks meeting the requirements of this Statement of Work (SOW).

BASIC REQUIREMENTS

Task I - Life Raft Deployment System Design and Integration with CH-46 Aircraft

A design and integration phase of a life raft deployment system for the CH-46 aircraft shall be conducted. Maximum use of existing technology, from previous life raft deployment development contracts, shall be made in such areas as automatic/semi-automatic activation system, manual/remote operated CO_2 cylinder valve and frangible pod opening hinge. A test plan shall be prepared for CO_2 valve tests and life raft deployment demonstrations.

Task II - Fabrication, Test and Demonstration

One (1) MARK 12A-1 life raft container pod with appropriate attachment fittings for interfacing with a simulated section of the CH-46 aircraft shall be fabricated. Hard points shall be added to the simulated aircraft section for attaching the pod. The aircraft simulated section shall be the same as used on the previous NADC life raft deployment test program and will be Government furnished.

Two (2) CO_2 cylinder valves with remote and manual operation capability shall be fabricated. MARK 12A-1 life rafts (two each) with CO_2 cylinders shall be furnished by the Government.

An automatic/semi-automatic life raft activation system shall be fabricated. The electrical control panel used for system activation in the previous contract shall be utilized and shall be Government furnished.

A minimum of one (1) CO_2 cylinder valve squib-operated test shall be conducted. A minimum of three (3) life raft deployment tests shall be demonstrated. Seven (7) days notice shall

be given to NADC before each demonstration so that Government personnel can arrange to witness the demonstration.

Technical Requirements

This section specifies the basic design and performance requirements for design and integration of an automatic/semi-automatic/manual life raft deployment system for the CH-46 aircraft.

Life Raft Pod

The life raft pod shall be designed as an integral package with life raft contained and capable of being quickly attached or removed on the aircraft. It shall have a clean aerodynamic shape and shall be constructed of fiberglass and metal. The cross sectional area shall be held to a minimum sufficient only for a compactly folded MARK 12A-1 life raft CO_2 cylinder and survival kit.

Pod Attachments

Design of attachments to the aircraft shall make use of existing structure to the maximum extent practicable. Necessary aircraft structural reinforcements shall be determined and the weight penalty estimated. The pods and the attachments shall be designed for locations on both sides of the aircraft, directly aft of the forward main hatches and on the lower section of the fuselage.

CO_2 Cylinder Valve

The manual/remote CO_2 cylinder valve, developed from a modified manual valve under a previous NADC contract, shall be productionized by designing the valve to be an

integral unit. The same squib, piston size and exhaust port locations and sizes shall be maintained. The squib, piston and CO_2 valve stem shall be modified to prevent misalignment and resulting over turning loads on the actuation lever and subsequent failure.

Activation System

Three (3) modes of system activation shall be employed. Two modes shall be electrical and the third shall be mechanical. An automatic mode shall be provided such that when the system is armed the life raft will be automatically deployed as soon as the rotor speed has decreased to 80 percent of normal speed, and a water sensing device determines that the aircraft is in the water and not on the land.

A semi-automatic mode shall be provided such that when the system is armed the pilot can elect to over-ride the rotor speed and water sensing inhibiting circuits and immediately fire the system.

In the event of primary or battery power failure or malfunction of the electrical system, a manual release system shall be provided. The manual system shall consist of a cable connected directly to the release mechanism in the CO_2 cylinder valve. A handle, tied to the other end of the cable, shall be located in an accessible position inside the occupied portion of the aircraft.

The automatic and semi-automatic life raft deployment activation system design, developed under previous NADC contract, shall be utilized in this program. The system shall be integrated with the CH-46 helicopter to the extent of determining locations and positioning for switches and test and

condition lights on existing cockpit panels or consoles. Drawings shall be made of the panel layout and the repositioning of other existing switches to accommodate the new components if necessary. The rotor speed system shall be investigated for an appropriate place to tie in the raft deployment actuation system. Tie-ins to power bus and battery system shall be determined. Existing system modifications and additional components shall be determined. Water sensing switch, selected under previous life raft deployment development contract, shall be evaluated for effects of the helicopter vibration spectrum environment. The evaluation shall also include the effect of static pressure differentials between the inside and outside of the aircraft during flight and its effect on inadvertent activation of the switch.

TASK I - DESIGN DEVELOPMENT

Life Raft Container Pod

The pod is designed as an integral package containing the life raft, pressure cylinder and survival kit. It is designed for quick attachment or removal from the aircraft requiring only 4 bolts. A clean aerodynamic shape was used for the pod which has a cylindrical body and hemispherical end caps (Figure 1). The diameter of the pod was held to 18 inches to minimize frontal area and aerodynamic drag. Length was adjusted to accomodate the volume of the folded MARK 12A-1 life raft with survival kit and pressure cylinder. Ends of the raft extend into the end caps when the raft is stowed in the pod.

A thermo-setting plastic (Kydex) was used for the principal material in fabricating the pod. This material was used to minimize cost for this one article manufacture. One half the number of molds were needed compared to fiberglass fabrication. A mold was made to form the hemispherical end caps and a mold was made to form each half of the cylindrical body. A mold was also required to form the bead reinforced stand-off structure.

Aluminum hinges were used to join the 2 halves of the cylindrical body, one on the top and one on the bottom. A standard hinge with one inch wide loops and stainless steel hinge pin is used for the bottom hinge. The top hinge is designed to be frangible. Three inch wide loops and an aluminum hinge pin are used. Pin diameter and loop width were selected to cause the pin to shear when a pressure of 5 psig is built up in the raft during inflation. Hinge shear load is determined as follows:

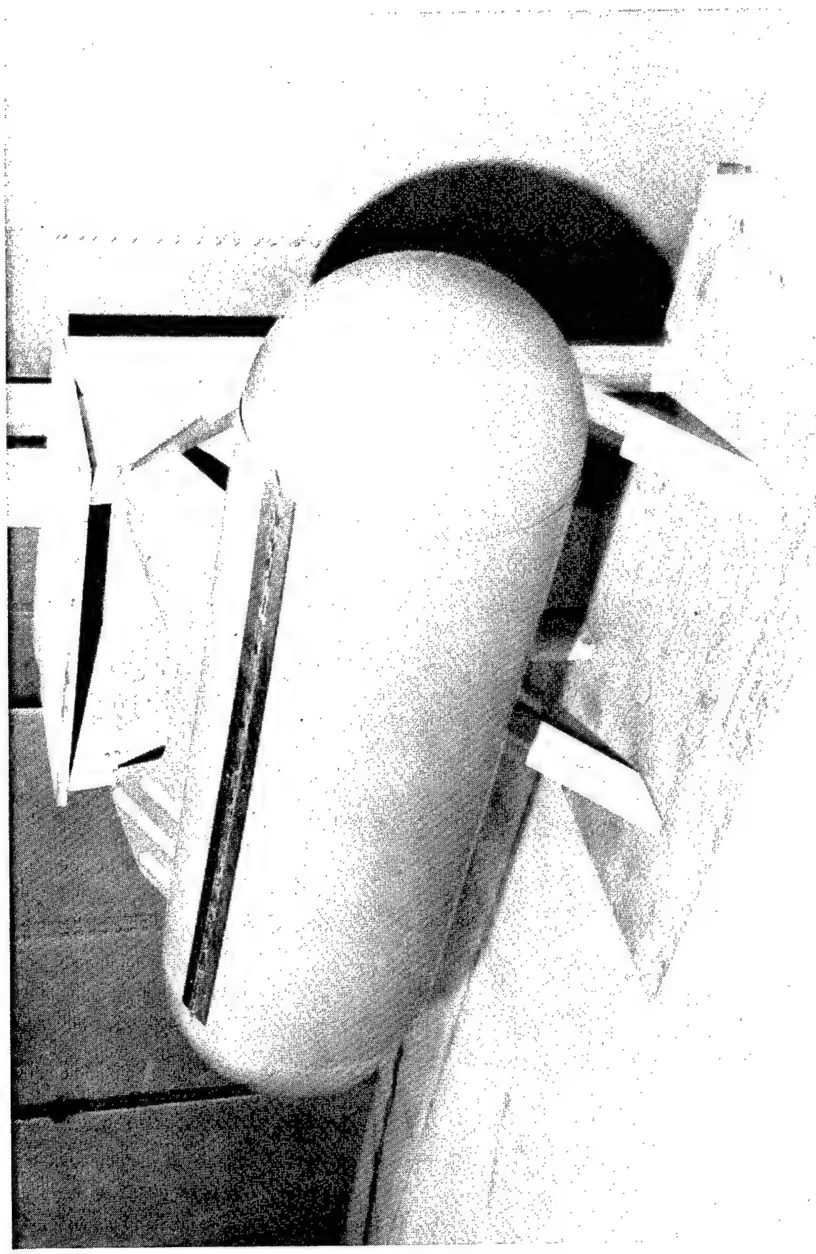


Figure 1. Life raft container pod.

$$T = \frac{DP}{2} \qquad T = \frac{(18\text{ in.})(5\text{ psig})}{2} = 45\text{ lb/in.}$$

For 3 inch loops, shear load is 45 x 3 = 135 lb. The pin was designed to shear at 135 pounds and pull-test data showed the pin to shear at 136 pounds.

The hemispherical caps, provided at each end of the pod cylinder, are held in place by a key strip bonded to the inside circumference of the cylinder at each end. Keyway grooves around the circumference of the end caps lock the caps to the cylinder until the upper hinge shears. When the cylinder opens during raft inflation, the end caps fall off (Figure 2). Lanyards can be provided to retain the caps.

POD ATTACHMENTS

The contract requirements specify that raft container pods, be located on both sides of the fuselage just aft of the forward entrance hatches. However this location was determined to be best for the emergency floats installation. A location just forward of the forward entrance hatches was selected as a suitable location for the rafts. Selection of the forward location however, prevents use of the aft section fuselage mockup used on the previous raft deployment development contract.

The previous life raft installation design utilized the side of the aircraft as one sice of the pod so as to minimize pod weight. However, this design necessitated the use of numerous attachments to secure the pod to the side of the aircraft. New requirements specify minimum attachments to permit quick removal or installation.

Structural web trusses, with stiffening beads molded in, were fabricated of the same thermo-plastic material as the

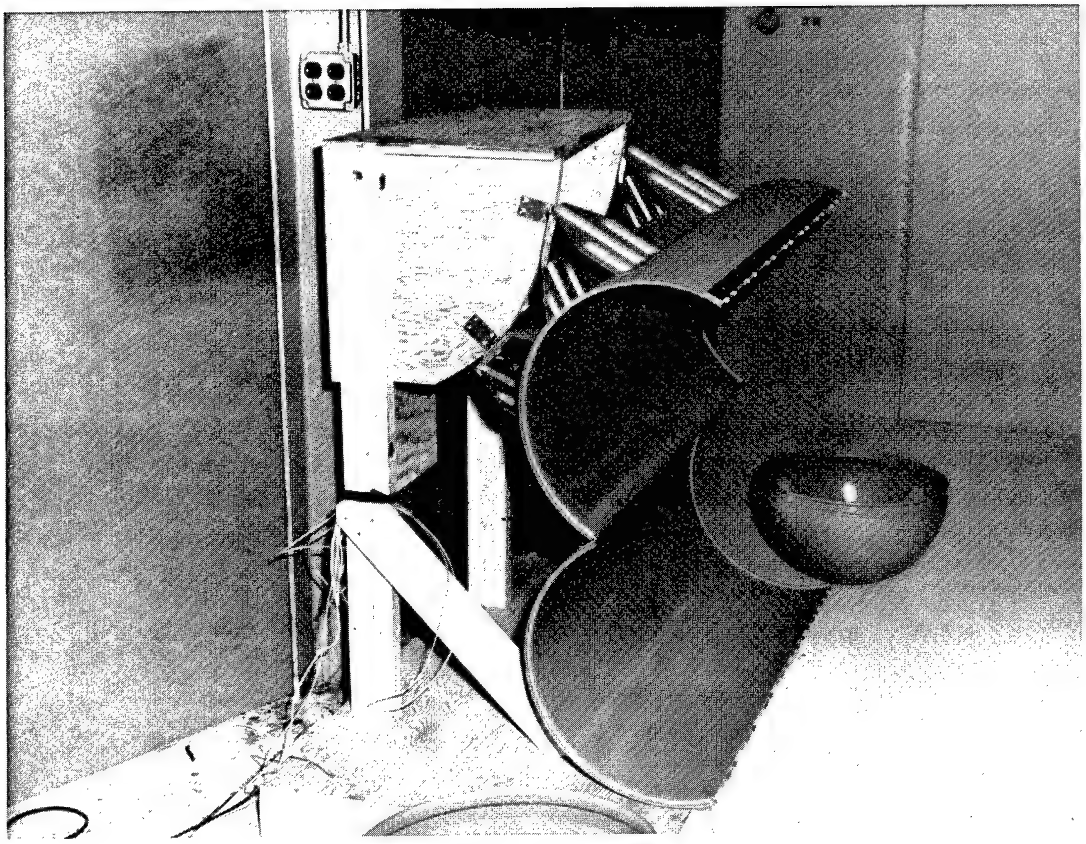


Figure 2. Pod opened after raft deployment.

pod. These members, bonded to the cylindrical portion of the pod, are used to provide stand-offs at a proper distance from the side of the fuselage for the least aerodynamic disturbance (Figure 2). Loads from the pod are distributed to 4 attachment points. Pod installation time is minimized, requiring fastening of only 4 bolts. Pods can be quickly removed for missions not requiring long over water flights, thereby saving weight and permitting extra cargo to be carried.

CO_2 Cylinder Valve

A valve which can be operated to discharge CO_2 into the life raft by manually pulling a cable or electrically firing a squib was developed from a modified manual valve under a previous NADC contract. However, problems were experienced with this valve due to the limitation on modifying an existing valve. Using the same principles of the previous design, a new valve was designed. The squib and piston were aligned with the valve stem in the CO_2 cylinder. These were misaligned in the previous valve due to its configuration. The squib selected is a standard squib used for engine fire extinguishers and is available in Navy inventory. One end of the piston chamber is threaded to accept the squib. A hole is provided in the opposite end of the chamber for a stem from the piston to extend through. Actuation of the CO_2 cylinder discharge valve is by a lever anchored at one end and contacted by the piston stem at the other end. The center of the lever rests on the CO_2 cylinder discharge valve. Support is provided on both sides of the actuation lever in the new design. Misalignment and a single side support had caused rolling of the lever, cracking of the case and miss fire of the previous valve. The squib firing chambers was made integral with the valve (Figure 3) permitting a reduction in length of the piston stem which had bent in the previous valve.

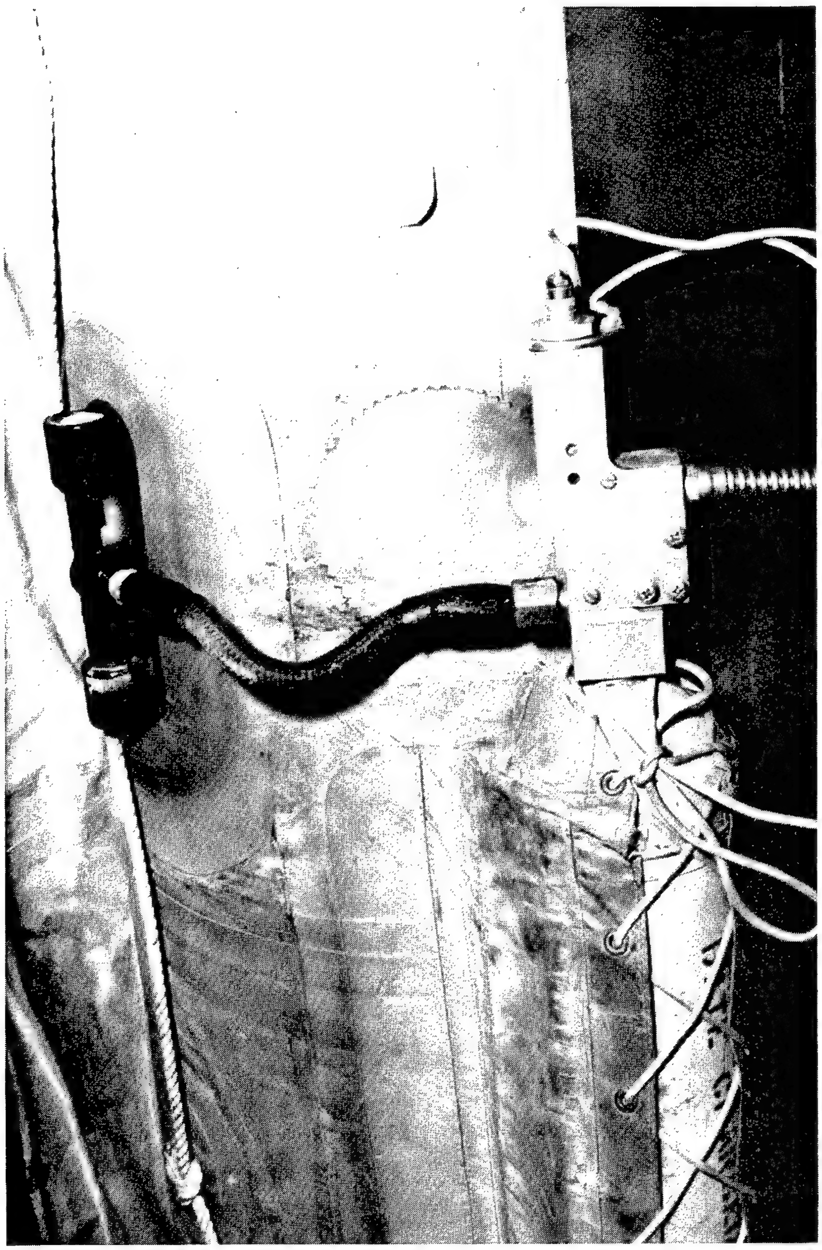


Figure 3. Electrical/mechanical operated CO_2 control valve.

The valve can be operated electrically or manually. Operation of the system electrically, consists of firing the squib which depresses the piston. A shaft, from the bottom of the piston and through the bottom of the cylinder, depresses a lever which opens the carbon dioxide cylinder valve. A springloaded pawl swings into place to hold the lever against the valve stem allowing carbon dioxide to continue to discharge into the raft.

Manual operation is performed by pulling a cable which rotates a cam, depressing the lever against the carbon dioxide cylinder valve stem. The manual mechanism works independently of the electrical-squib-fired mechanism. Both systems could be operated simultaneously without interference.

Activation System

Three (3) modes of system activation are employed. Two modes of electrical activation, automatic and semi-automatic are used and the third is mechanical activation.

Electrical System Activation

The electrical system can be operated in either the automatic mode or the semi-automatic mode. In the semi-automatic mode certain functions of the automatic system are bypassed by an override switch. A test mode is also included. The automatic mode will function to fire the squibs and deploy the life raft when all of the following events occur:

a. 28 volts is available to the system.

b. The Arm switch is placed in the Arm position.

c. The aircraft is on the water and the water sensor switch closes.

The Arm switch should be activated whenever the aircraft is engaged in over-water operations. Life raft deployment would then automatically occur when inadvertent water entry is made, even if the crew were incapacitated by the impact. In the event an intentional water landing is made and the rotor shut down, the Arm switch should be placed in the "Off" position.

The semi-automatic mode will function to fire the squibs and deploy the life raft when all of the following events occur:

a. 28 volts is available to the system.

b. The Arm switch is placed in the Arm position.

c. The crew elects to deploy the life raft by placing the semi-automatic (override) switch in the "On" position.

The test mode will function to verify continuity through the squib filaments when all of the following events occur:

a. 28 V.D.C. is available to the system.

b. The test switch is placed in the test position applying 28 volts and ground to the squib through a dropping resistor and lamp. The resistor reduces the current through the squib to a safe level of below one ampere; 8 amperes are required to fire the squib.

Mechanical System Activation

In the event of primary or battery power failure or malfunction of the electrical system, a manual release system is provided. The manual system consists of a cable with pull handle on one end and a ball on the other end which engages a cam in the valve head. As the cable is pulled, the cam is rotated against a lever, depressing the lever against the CO_2 cylinder valve stem and releasing the CO_2 into the raft.

Electrical Actuation Panel

An electrical bread board panel (Figure 4) was made for system operations during the test program and is described later. The panel would be more compact and would have edge lighting for aircraft installation. Guarded switching would also be used.

For the aircraft, an investigation was made of existing models of the CH-46 to determine a suitable location for the life raft deployment control panel. The criteria used for selecting a location was that the panel be readily accessible to both the pilot and copilot. The overhead panel and center console, accessible to both pilot and copilot, were investigated and no available space was found. As has been done in the past, additional panels have been added to the sides of the center console (Figure 5). Additional room is available along the sides for not only the automatically deployed life raft control panel but also the emergency flotation system control panel.

Need for a rotor speed inhibiting switch was investigated. The value of preventing inadvertant life raft deployment during a routine landing on the water with rotors turning was weighed against the possibility of blades striking the water and causing rapid rollover before rotor speed decreased and the rafts were deployed. Although a provision for a rotor speed switch was included in the test control panel and the system schematic, it is recommended that inhibiting system activation until rotor speed decays, be deleted.

Locations for tie-ins to power sources will be dependent upon the location of the control panel on the center console. Sources for power are readily available in the console and should present no problems.

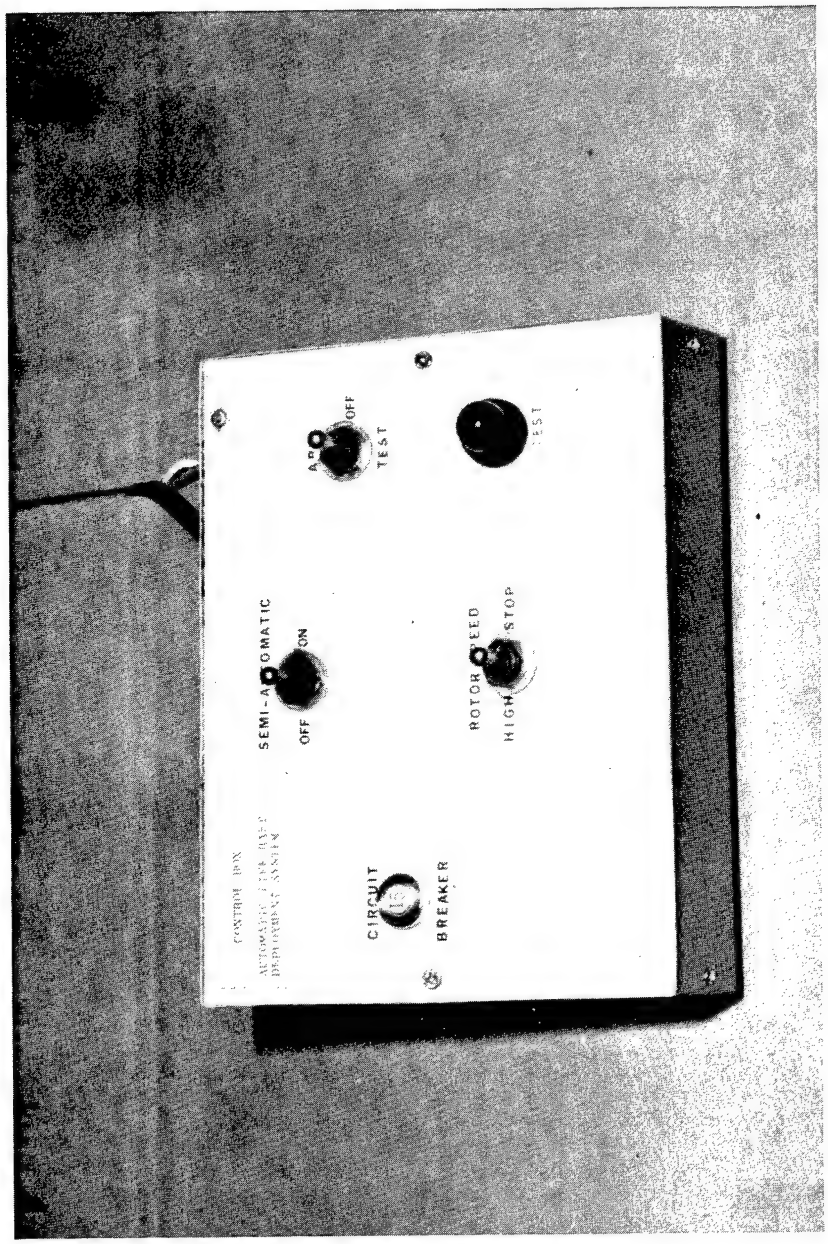
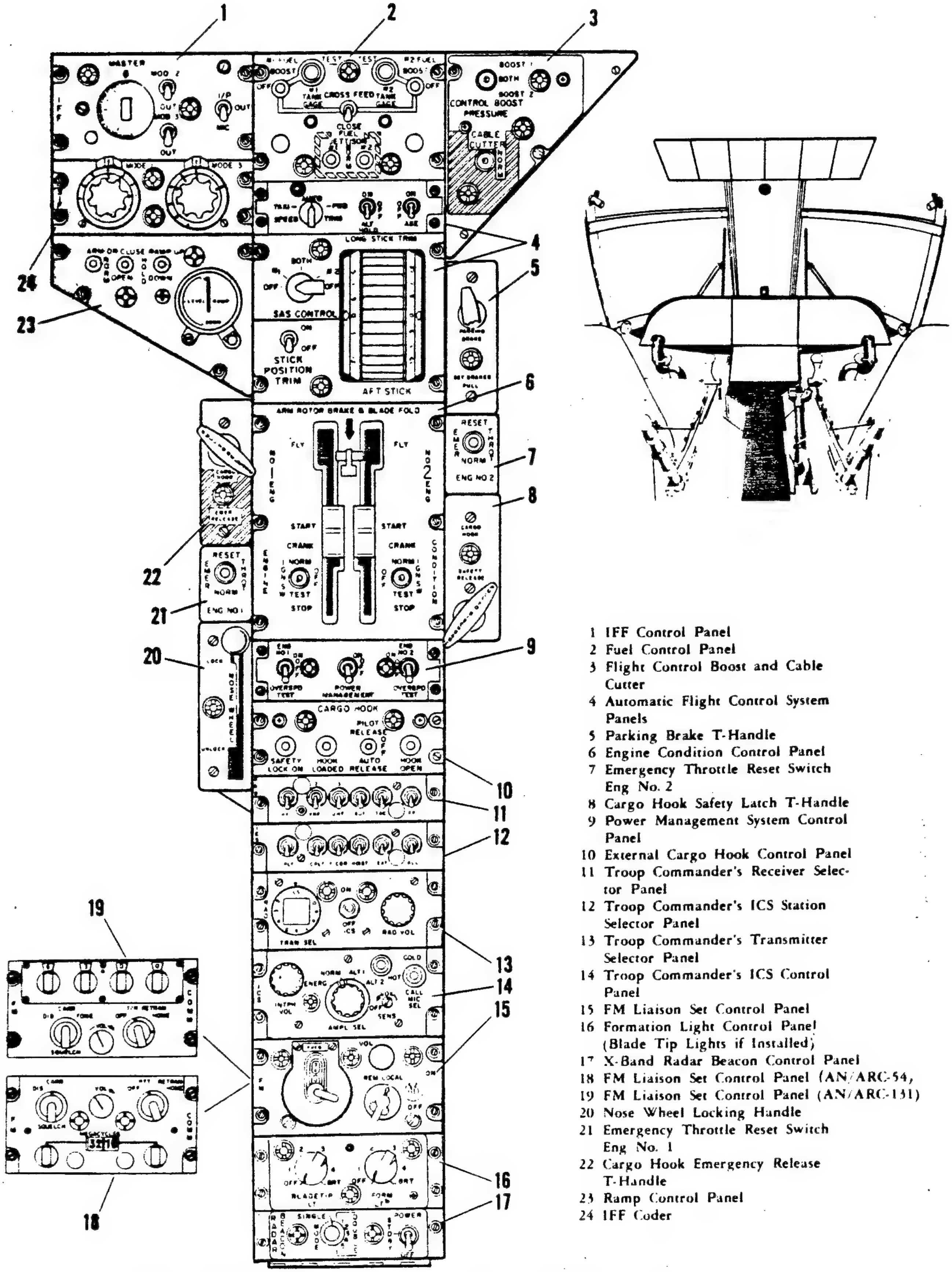


Figure 4. Breadboard electrical panel for test operations.



1 IFF Control Panel
2 Fuel Control Panel
3 Flight Control Boost and Cable Cutter
4 Automatic Flight Control System Panels
5 Parking Brake T-Handle
6 Engine Condition Control Panel
7 Emergency Throttle Reset Switch Eng No. 2
8 Cargo Hook Safety Latch T-Handle
9 Power Management System Control Panel
10 External Cargo Hook Control Panel
11 Troop Commander's Receiver Selector Panel
12 Troop Commander's ICS Station Selector Panel
13 Troop Commander's Transmitter Selector Panel
14 Troop Commander's ICS Control Panel
15 FM Liaison Set Control Panel
16 Formation Light Control Panel (Blade Tip Lights if Installed)
17 X-Band Radar Beacon Control Panel
18 FM Liaison Set Control Panel (AN/ARC-54)
19 FM Liaison Set Control Panel (AN/ARC-131)
20 Nose Wheel Locking Handle
21 Emergency Throttle Reset Switch Eng No. 1
22 Cargo Hook Emergency Release T-Handle
23 Ramp Control Panel
24 IFF Coder

Figure 5. CH-46 center console panels.

Water Sensing Switches

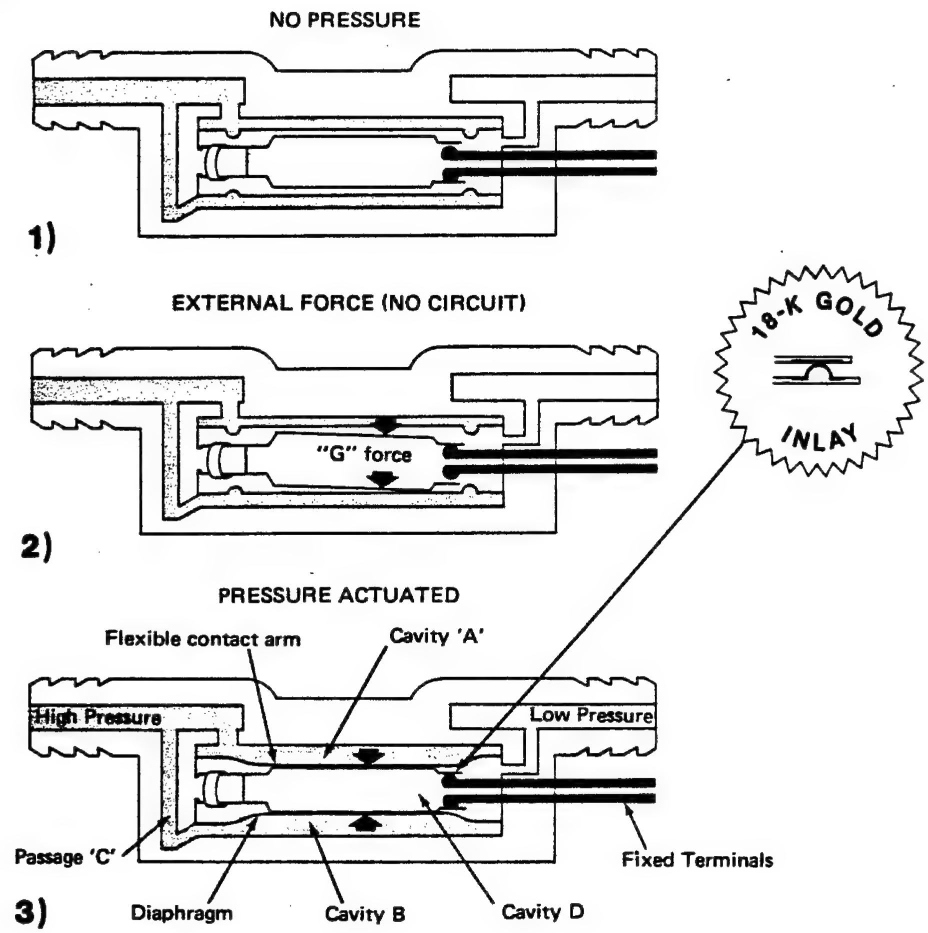
The Fairchild water pressure switch, previously used for the automatic life raft deployment, was investigated and evaluated. Provisions are made in the switch to prevent inadvertant activation due to vibration or accelerations. Figure 6 shows the effect of these forces on the switch and how no circuit is completed. Normal position and pressurized actuated positions are also shown in Figure 6. Switches are available in a range from 1.5 to 50 inches of water (Figure 6). The only disadvantage of the switch is that an aircraft connector is not provided. To use the switch, it will have to be installed in a box with suitable electrical connector attached.

A second water pressure switch was investigated. This switch produced by Neo-dyne, has an adequate electrical connector, but is much larger and much heavier than the previous switch (Figure 7a). The small switch weighs .002 lb compared to .78 lb for the larger switch. Redesign for weight reduction would be necessary before the larger switch is acceptable for use in the aircraft.

A third water switch using a float principle and manufactured by Reeves was tested (Figure 7b). This switch was lighter than the second switch weighing .13 lb. It will function up to 50 degrees from vertical in water and will function without water when inverted. This feature will be an advantage if the aircraft goes into the water in an inverted attitude.

Weight Impact

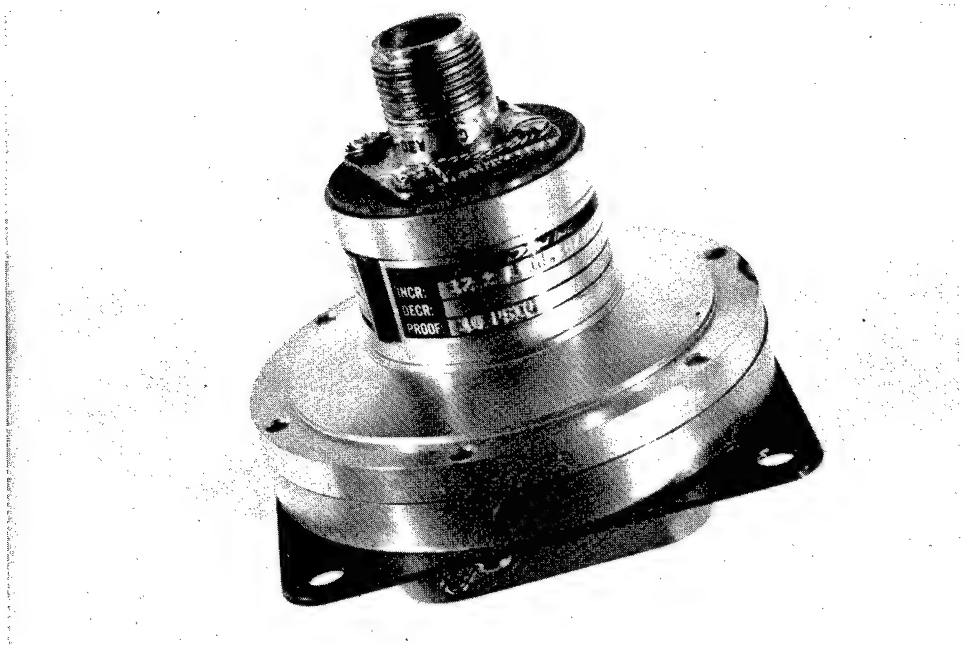
Weight of the life raft system (including 2 MK12A-1 life rafts) is divided into aircraft empty weight and mission weight. Mission weight items are removable, while aircraft empty weight items are permanently installed in the aircraft. These areas follow:



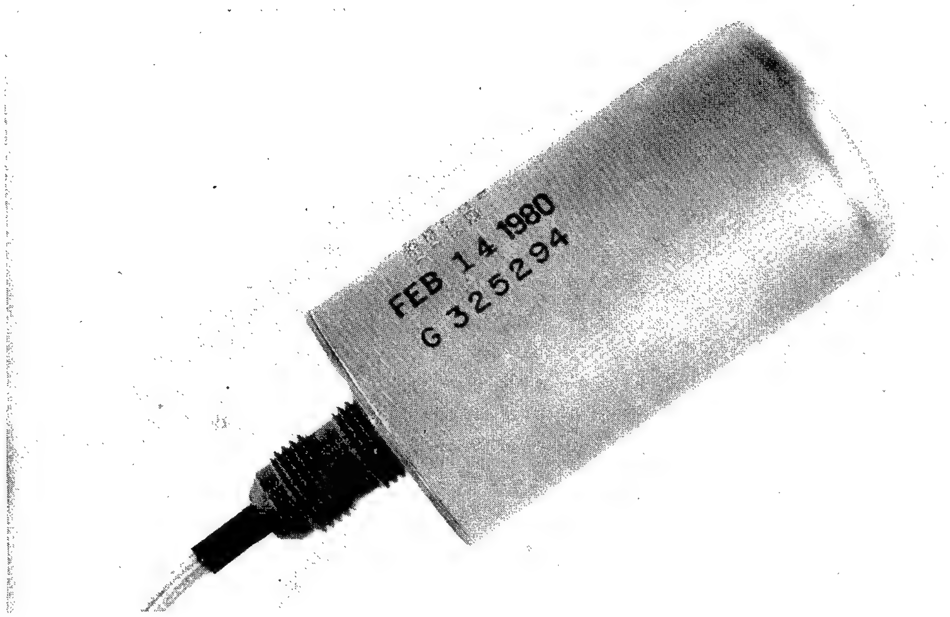
AVAILABLE IN THE FOLLOWING STANDARD ACTUATION RANGES

No Dash	-1.5	-3.0	-4C	-6C	-8C	-10C	-12C	-15C	-20C	-30C	-40C	-50C
Nominal Actuation (in. w.c. ± 20%)	1.5	3.0	4	6	8	10	12	15	20	30	40	50
mm HG ± 20%	2.8	5.6	7.4	11.2	14.9	18.6	22.3	27.9	37.2	55.8	74.4	93.0

Figure 6. Water pressure sensing switch.



a. Pressure switch.



b. Float switch.

Figure 7. Water sensor switches.

1. Mission weight - 276 pound (pods, life rafts, CO_2 cylinders, survival kits).

2. Empty weight - 5 pound (switch panel, wiring, water switch, structure).

TASK II - FABRICATION, TEST AND DEMONSTRATION

Test Fixture

The Government furnished simulated section of the CH-46 helicopter, specified by the Statement of Work to be used for system demonstrations, could not be used. A section of the aircraft with a different outer contour was selected for pod installation. Therefore a new test fixture with the appropriate contour was designed and built (Figure 8). Four hard points were provided on the test fixture for attaching the pod (Figure 8).

Test Control Panel

A control panel was fabricated with 3 switches, a circuit breaker and a test light (Figure 4). The panel was wired in accordance with the wiring diagram shown in Figure 9 and the electrical schematic (Figure 10).

The semi-automatic mode was checked by replacing the squib with a volt meter. Twenty-eight volts were applied to the control panel through the circuit breaker. The Arm switch was placed in the Arm position. This position completes the circuit from the squib up to the grounding switch and to the rotor speed switch. The rotor speed switch was allowed to remain in the open position simulating rotor speed above 80 percent of normal rotation. The water sensor switch also remained open. The grounding switch is ganged with the B+

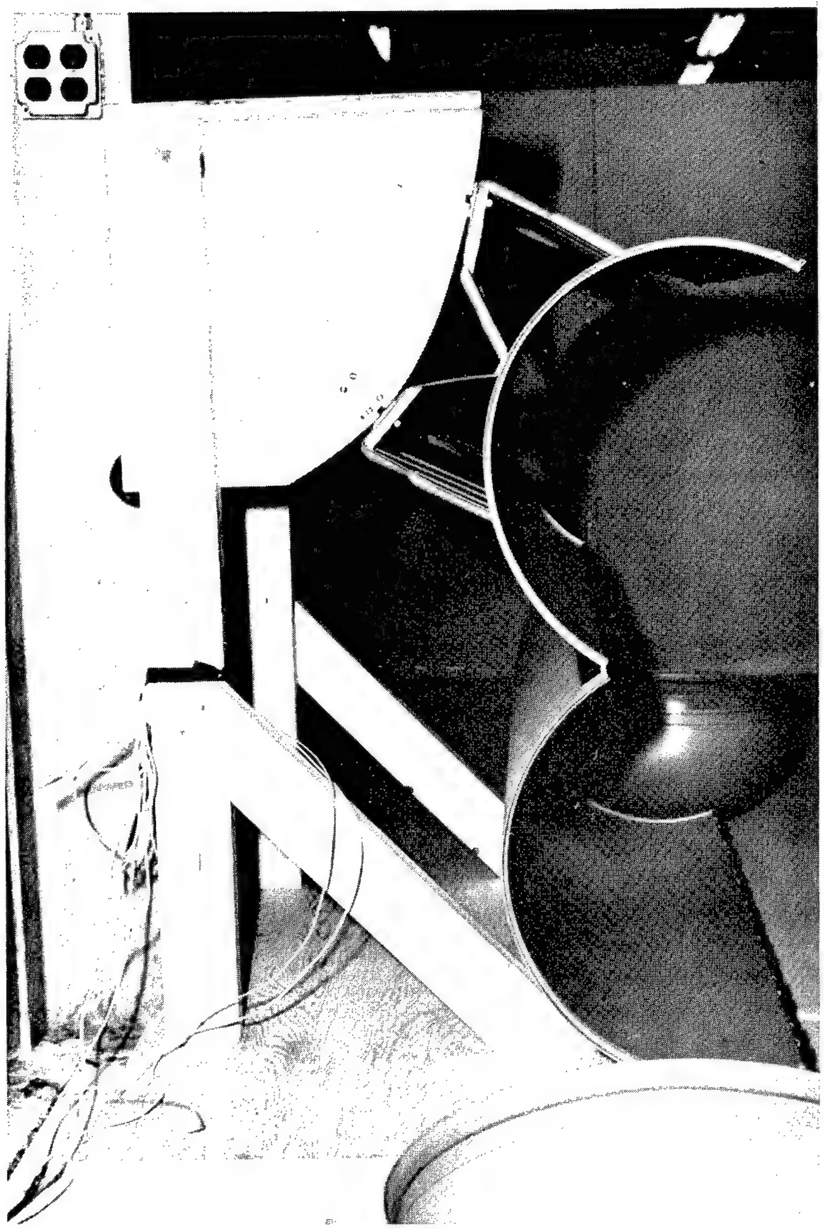


Figure 8. Test fixture simulating CH-46 fuselage.

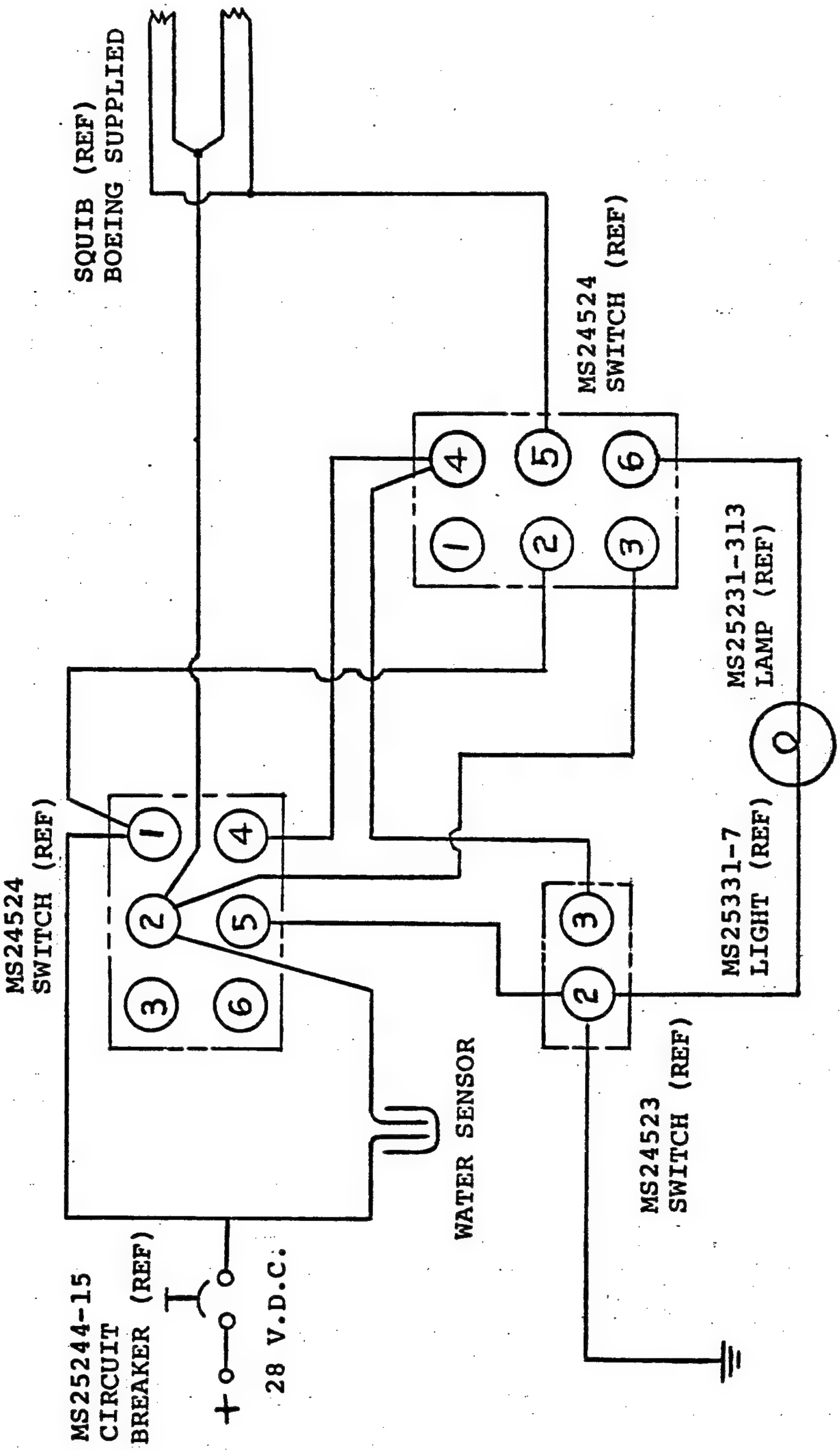


Figure 9. Test panel wiring diagram.

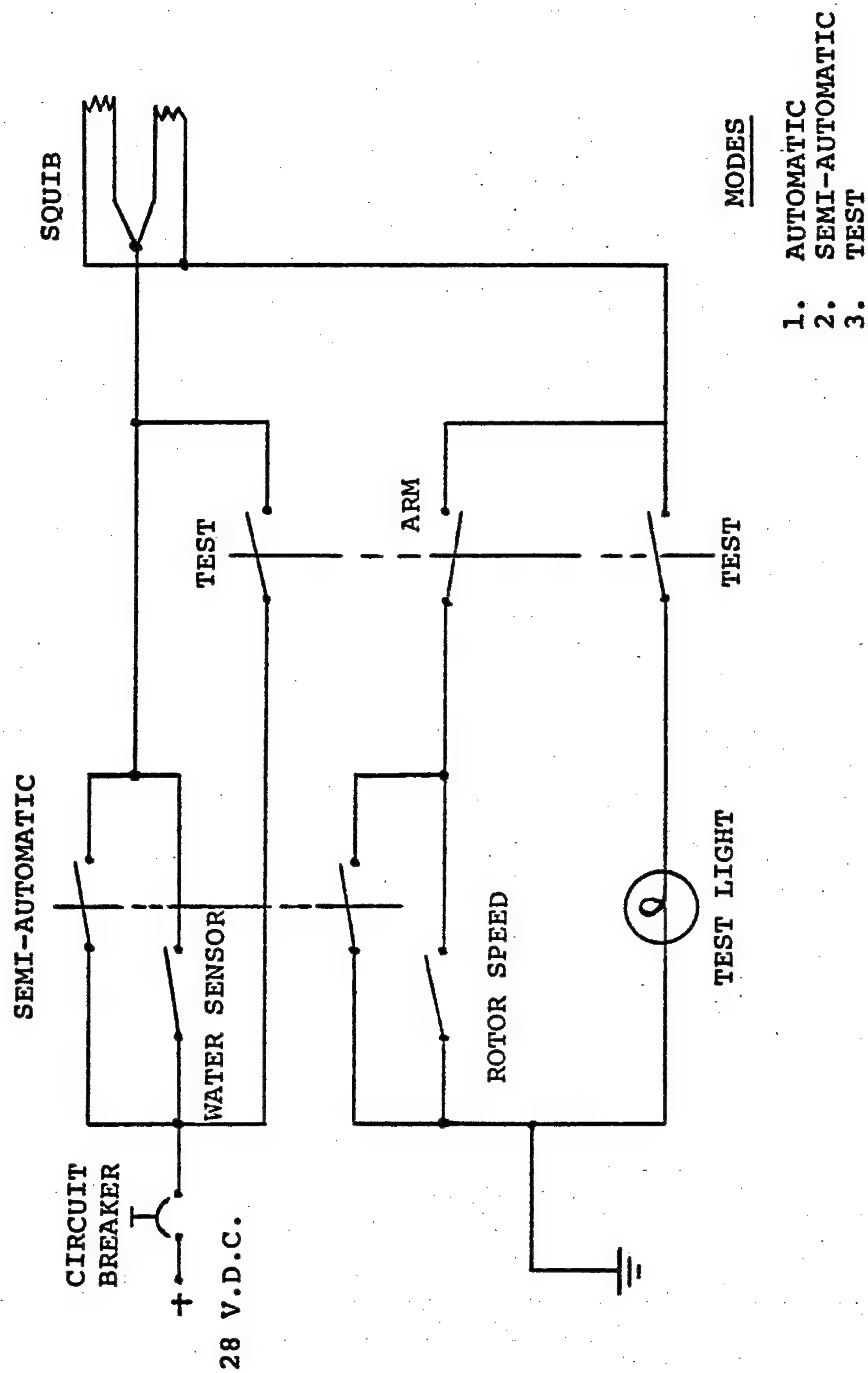


Figure 10. Test panel electrical schematic.

semi-automatic (override) switch, both of which are closed simultaneously to initiate the raft deployment. When this switch was placed in the "On" position 28 Volts were recorded at the squib location.

The automatic mode was checked by allowing the volt meter to remain in the place of the squib. Twenty-eight Volts were applied to the control panel through the circuit breaker. The arm switch was placed in the "On" position and the rotor speed switch was placed in the low speed or closed position. This position completed the circuit from the ground side of the squib through the Arm switch, through the rotor speed switch to power ground. B+ was applied to the circuit by placing a plastic tube from the water sensor switch into a cup of water. The circuit was completed and 28 volts was recorded at the squib location.

The system test circuit was checked by placing a squib in the circuit. Twenty-eight volts were applied to the control panel. The Arm switch, semi-automatic switch and rotor speed switch were in the "Off" position. The test switch was placed in the test position and the test lamp lit. The test switch applied B+ and ground to the squib through the test lamp. This test verified the continuity of the circuit through the filaments in the squib.

<u>Raft Folding Procedure</u>

The life raft was prepared for installation by placing it unfolded on the floor. A vacuum pump was utilized to remove the air. Folding consisted of rotating the front and back sections back on top of the center section so that a width of 54 inches was obtained. The survival kit was simulated by stuffing the container with boxes and styrofoam pellets and then placing it under the bottom fold of the raft. An attempt was made to fold the raft in an accordian manner to

facilitate deployment. This configuration was measured and found to exceed the 18 inch pod by several inches. The raft was then unfolded then rolled up maintaining the 54 inch width. Folding and rolling was accomplished so that the area where the CO_2 pressure cylinder was laced was located on the outer edge of the roll. A diameter slightly less than 18 inches was measured, small enough to fit into the 18 inch diameter pod.

Raft Installation Procedure

Installation of the raft in the pod was accomplished by first; opening the 2 halves of the cylindrical section by removing the frangible hinge pin (Figure 1). The rolled raft was placed on one half of the cylinder and the other half was rotated over the raft, Both end caps were snapped into place in the ends of the cylinder. Pressure was applied to the sides of the cylinder until the hinge halves lined up. A frangible aluminum hinge pin was inserted into the hinge completing the pod closure. Electrical wires were connected to the squib wires which had been fed through a hole in the side of the pod. The manual release cable is extended through a hole in the side of the pod.

System Demonstration

Test Preparation

The raft with survival kit was folded and packed into the pod. The carbon dioxide cylinder with squib-operated valve was attached to the raft and the hose connected. Electrical wiring was attached to the squib and passed through a hole in the side of the pod. A slip-type quick-disconnect was used in the wire between the pod and the raft cylinder. The pod half was rotated upward about the lower hinge, the end caps attached and the upper frangible hinge pin inserted.

A continuity check of the squib system was made by applying 28 volts D.C. to the control panel and placing the test switch in the test position. The test lamp lit verifying the system continuity.

Motion picture cameras were set up to record the firing. Final checks were made and the life raft pod system was ready for the demonstration (Figure 11).

Test 1 - Semi-automatic System Demonstration

With a countdown of 5, the Arm switch on the control panel (Figure 4) was placed in the Arm position, cameras were started and the system was fired by placing the semi-automatic mode switch in the on position. The squib was heard to fire, however the raft did not deploy.

An inspection of the system was made to determine the cause of the system failure. The hinge pin was removed and the pod opened. Removal of the pressure cylinder required disconnecting the squib wiring, disconnecting the hose and unlacing the cylinder retainer sleeve. Inspection of the firing mechanism showed that the squib had fired the piston against the lever and the lever was depressing the cylinder valve stem and the lever was held in this position by the spring loaded pawl. Conclusions were reached that the valve in the pressure cylinder had failed.

The pressure cylinder remained fully charged which was verified by its weight. Pressure had to be relieved and the only way this could be done without destroying the cylinder was to turn the valve head on the cylinder until it began leaking. After the pressure was relieved, the valve was removed from the cylinder and the valve stem was found to have been driven through the valve disk. The valve, which had been part of the Government furnished standard life raft cylinder, was made with a teflon disk molded onto the valve stem.

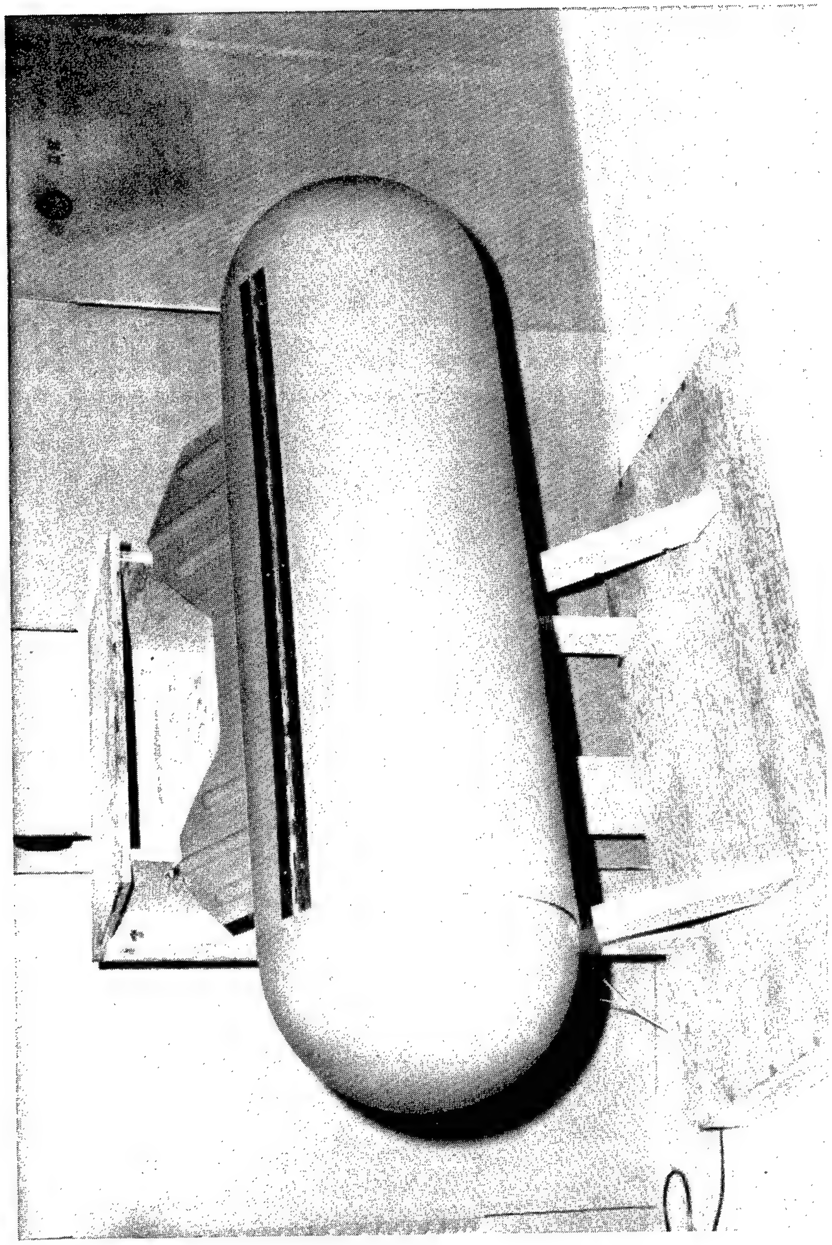


Figure 11. Pod loaded with life raft, ready for test.

Another model of the life raft pressure cylinder was obtained with a valve having a metal disk attached to the valve stem in a more secure manner.

The problem with the new valve was that it would not fit on the same valve seat as the failed valve. A new valve seat was required which could be inserted into the remote/ manual valve head so that the alternate valve configuration could be used.

Test Preparation

In preparation for a rerun of a semi-automatic system demonstration, the valve head was reworked for the alternate valve installation. The cylinder was recharged with CO_2 and installed in the raft. Installation of the raft was the same as for test 1.

Test 2 - Semi-automatic System Demonstration

A countdown of 5 was given and with the Arm switch in the Arm position and cameras rolling, the system was fired by placing the semi-automatic mode switch in the on position. The squib fired and CO_2 was discharged into the float. As the float inflated inside the pod, pressure was exerted on the frangible hinge pin which sheared and the pod opened releasing the raft. Raft opening sequence is shown in Figure 12. The fully inflated raft is shown in Figure 13.

After the test, an inspection of the pod was made. No damage or distortion was found in the pod container, the end caps or the frangible hinge. The frangible hinge pin had sheared at each of the 3 inch spaced loops.

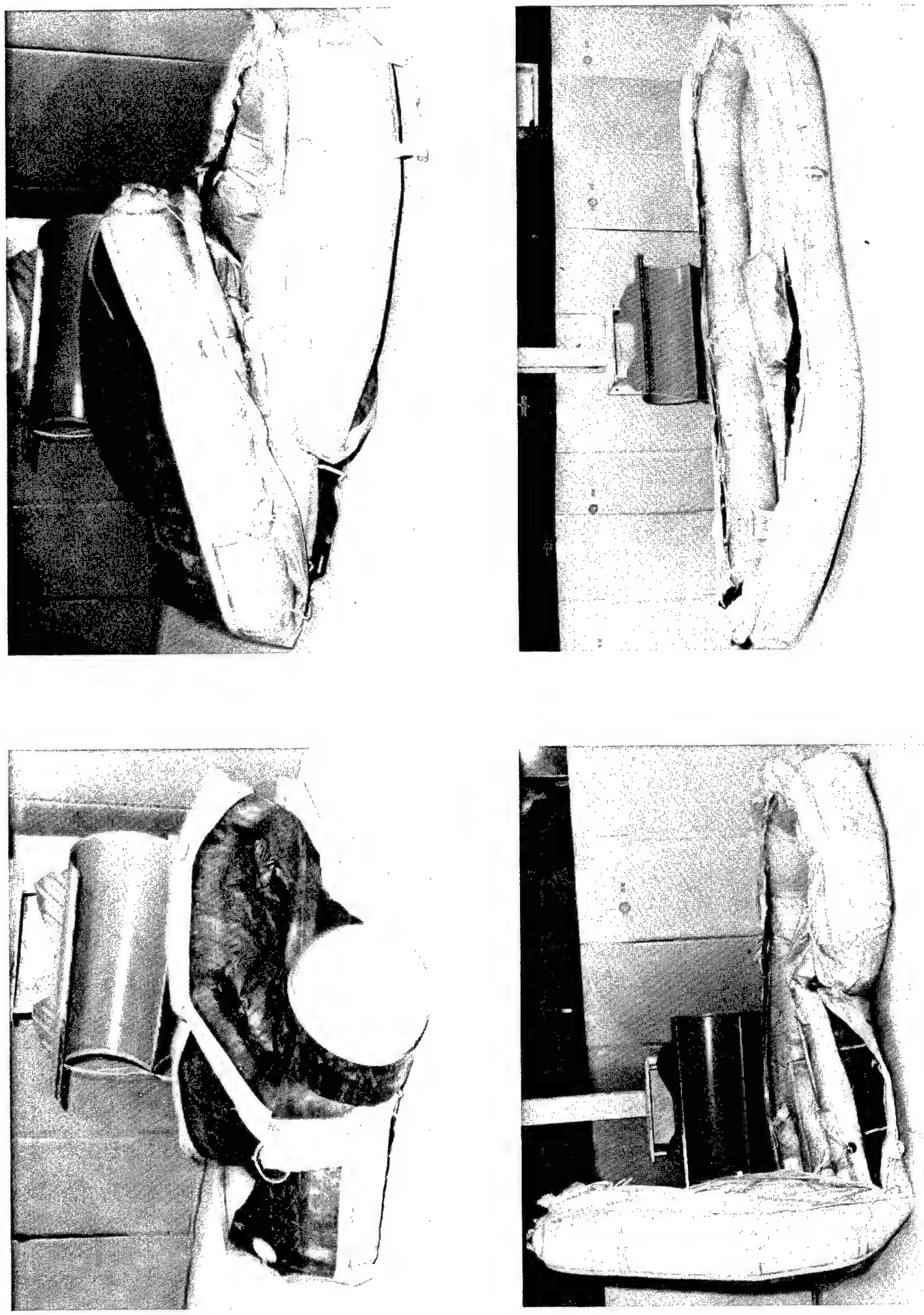


Figure 12. Raft deployment sequence.

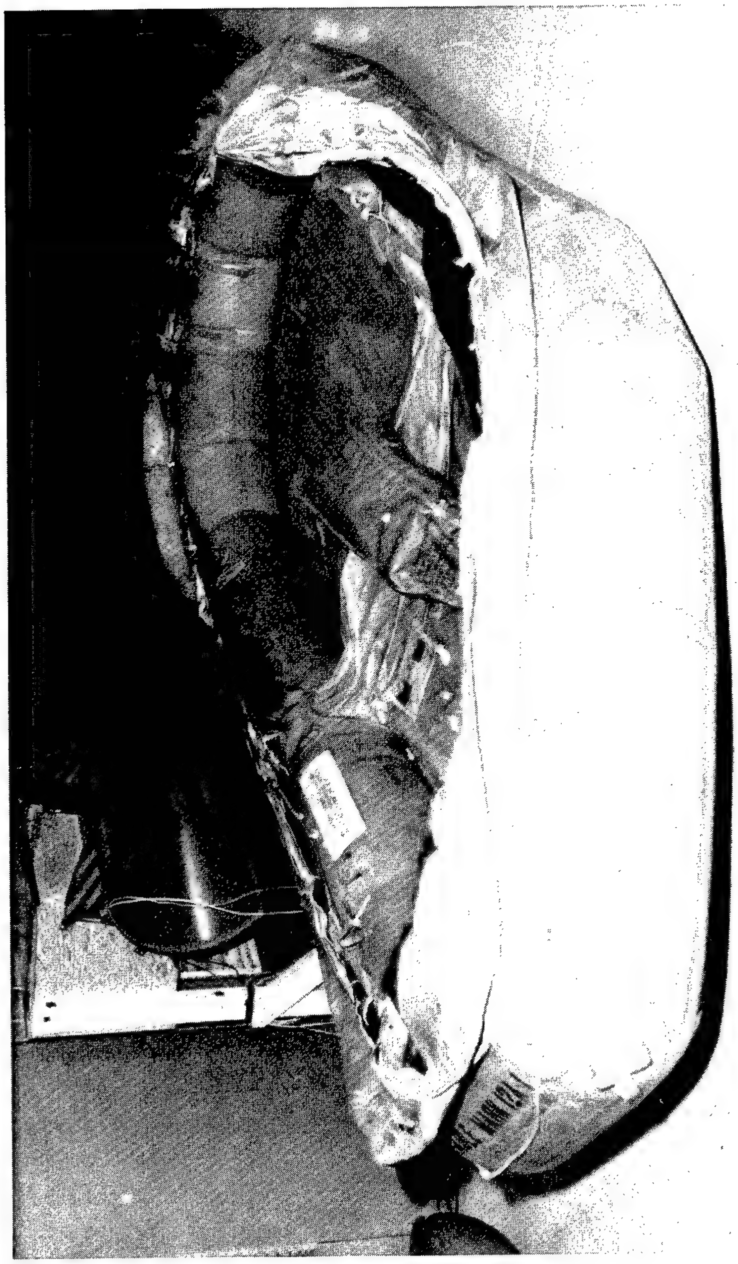


Figure 13. Fully inflated raft.

The remote/manual CO_2 control valve (Figure 3) was disassembled and was found to have functioned properly. The lever was pressed against the CO_2 cylinder valve stem and the spring loaded pawl had swung into place keeping the lever depressed.

Test Preparation

In preparation for the automatic raft deployment system demonstration, the CO_2 cylinder control valve head was disassembled, checked, cleaned and reassembled. Pyrotechnic products from the squib had jammed the piston but after cleaning, the piston moved freely in the squib firing chamber. CO_2 cylinder recharging and installation in the raft were accomplished and a new squib installed. The raft was evacuated with a vacuum pump and then folded the same as for the previous test. The raft was placed in the pod, the end caps installed and the frangible hinge pin inserted.

System activation was to be accomplished in the automatic mode, so a container of water was provided. A hose was connected at one end to the water sensor switch and the other end of the hose was to be inserted into the water container for system activation. The water sensor system was checked by placing an ohm meter in the place of the squib. With the "Arm" switch in the "On" position and the "Rotor Speed" switch in the "Low" position, the water sensor hose was inserted into a container of water. Continuity was indicated when the hose reached a depth of approximately 13 inches. The squib was reinserted and checked by placing the test switch in the "Test" position. When the test light lit, continuity was verified.

Test 3 - Automatic System Demonstration

With a countdown similar to the previous test, the "Arm" switch was placed in the "Arm" position and the "Rotor

Speed" switch was placed in the "Low" position. The firing system was initiated when the hose was inserted into a container of water (Figure 14). As the hose reached a depth of 13 inches the squib fired and CO_2 was discharged into the float. Pressure built up inside the raft causing the frangible hinge pin to shear and the pod opened releasing the raft. Raft deployment sequence is shown in figure 15 and the fully deployed raft is shown in figure 16.

After the test, an inspection of the pod and CO_2 control valve was made and no damage or distortion was found. The water switch had initiated the system and the frangible hinge pin and control valve had functioned properly as in the previous test.

Test Preparation

In preparation for the manual raft deployment system demonstration the CO_2 cylinder control valve head was disassembled, inspected, cleaned and reassembled. Although the pyrotechnic portion of the valve will not be used in the manual firing test, it was necessary that the complete system be functional. With the CO_2 cylinder recharged, a squib was inserted into the valve but wires were not connected. Raft evacuation and packing were the same as on previous tests. The manual pull cable was inserted through a hole in the pod and a lanyard attached to provide a safe distance for the operator (Figure 17).

Test 4 - Manual System Demonstration

The system was fired by pulling the manual release cable. The cable, after pulling, came free of the control valve head and through the hole in the pod allowing the raft to be completely free. As the cable rotated the cam against the actuation lever, gas was released into the raft when the lever depressed the CO_2 valve. Although the spring loaded pawl

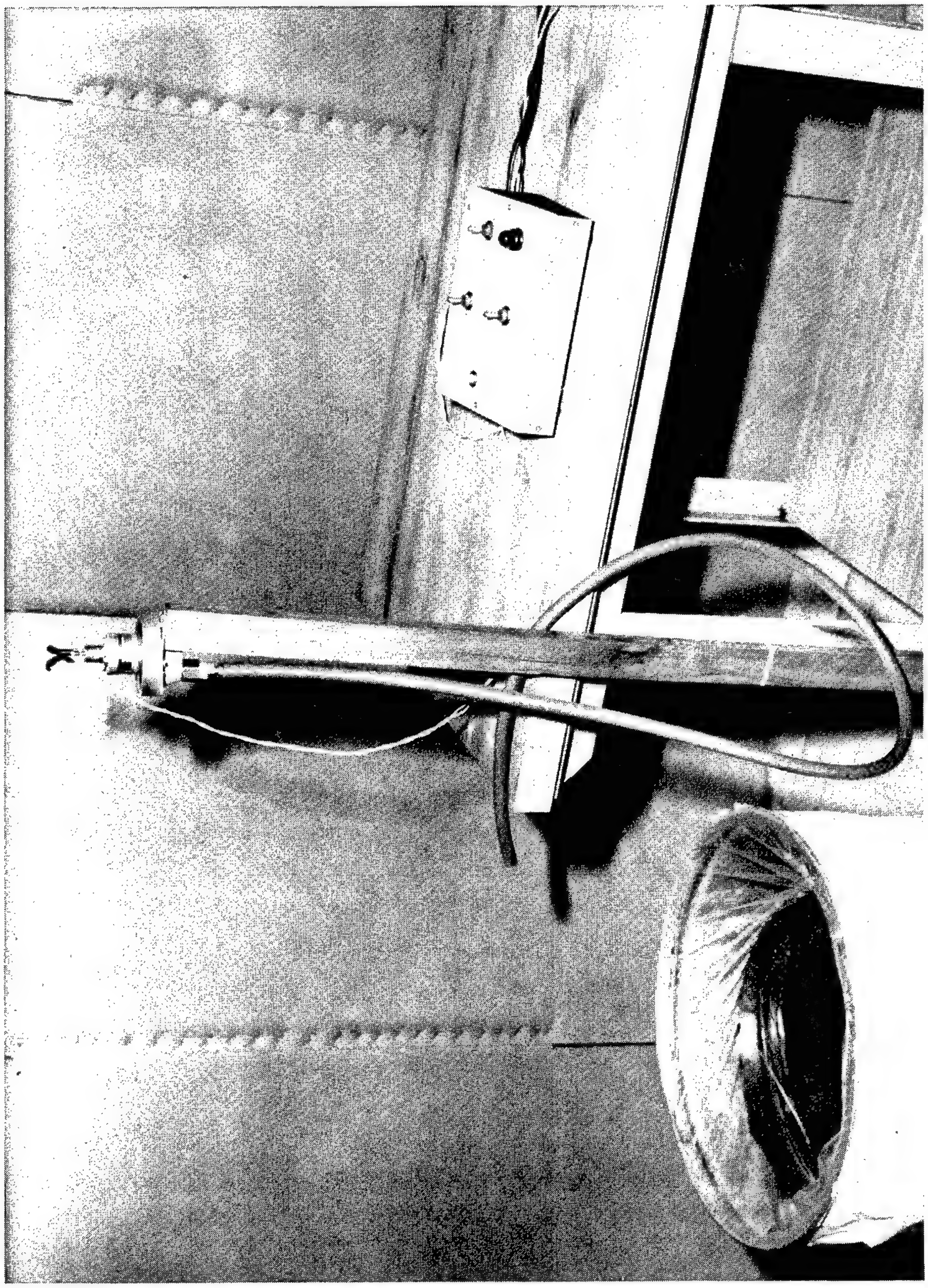


Figure 14. Water sensor test set-up.

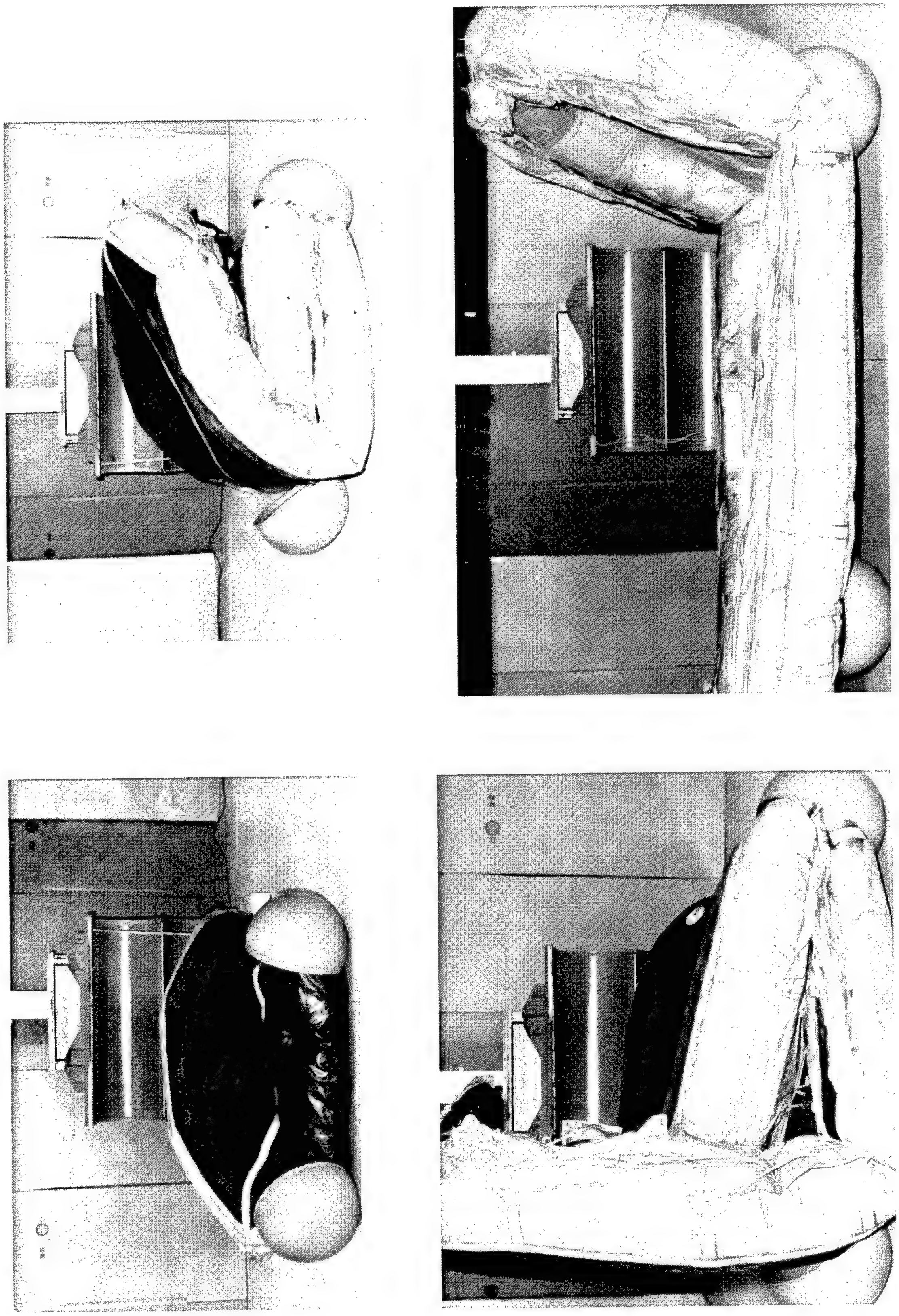


Figure 15. Raft deployment sequence.

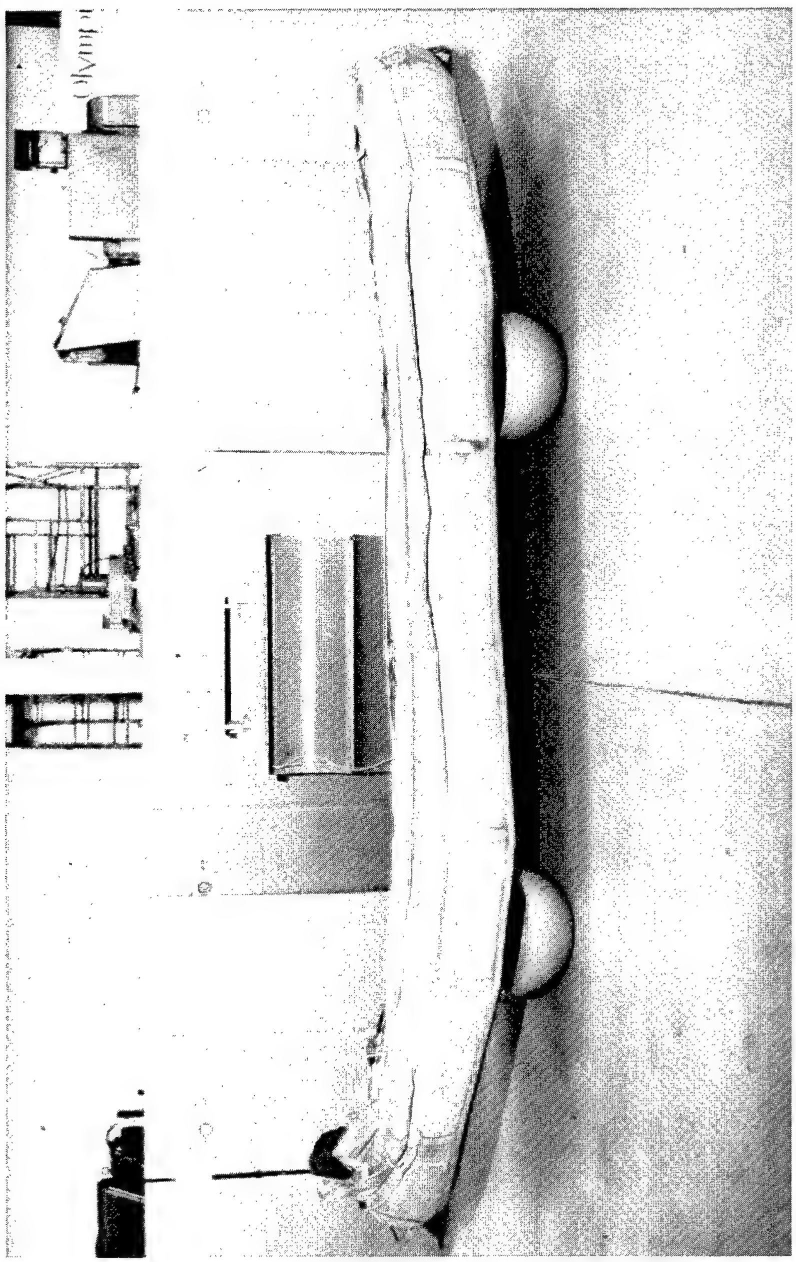


Figure 16. Fully deployed raft.

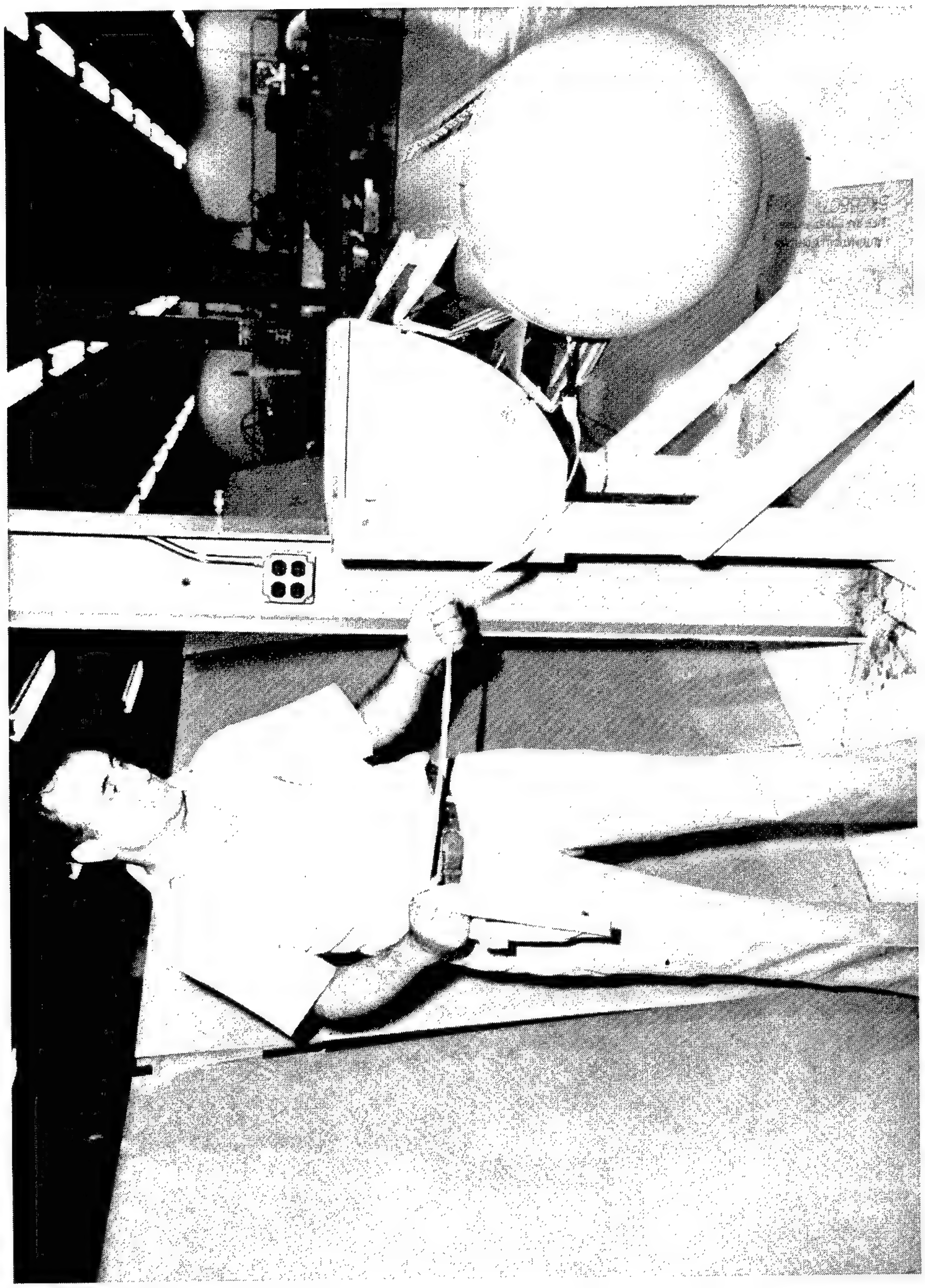


Figure 17. Manual firing cable with lanyard attached.

swung into position against the lever, this function is not necessary for the manual operation as the cam maintains the lever in position. Pressure built up in the raft and the frangible hinge pin sheared opening the pod cover. Deployment sequence of the raft is shown in figures 18 and 19.

CONCLUSIONS AND RECOMMENDATIONS

The automatically deployable life raft system was successfully demonstrated using automatic, semi-automatic and manual means of initiation. During remote initiation of the system the squibs fired properly driving the piston shaft against the CO_2 valve depression lever. The lever was maintained against the valve stem by the action of a spring loaded pawl which swings into place during initiation.

Mechanical initiation functioned properly with the rotary cam depressing the lever and maintaining the CO_2 valve in the open position. CO_2 flowing into the raft pressurizes the raft in the pod until 5 psig is reached. At this pressure the frangible hinge pin sheared successfully in each test and the pod opened releasing the raft. The raft deployed right side up in all the tests. No damage or distortion was found in the control valve mechanism, the pod structure or the pod opening release system.

It is recommended that the automatically deployed life raft system developed and demonstrated under this program be utilized on the CH-46 helicopter under a retrofit program. The system is also adaptable to other existing helicopters in the Navy inventory. Modifications to adapt the pod to other aircraft contours could be accomplished by providing a variable bracket which attaches the pod to the side of the aircraft.

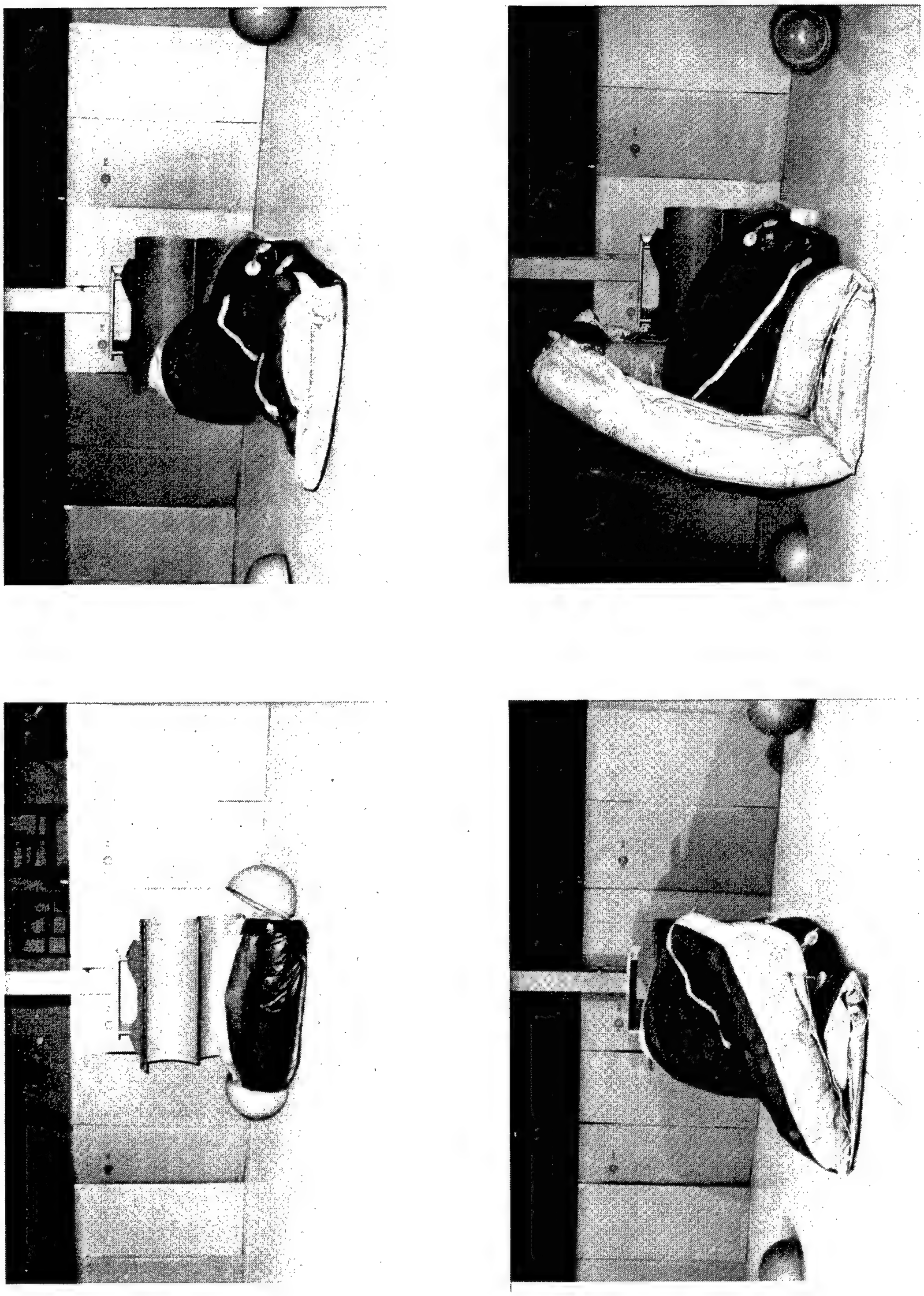


Figure 18. Raft deployment sequence.

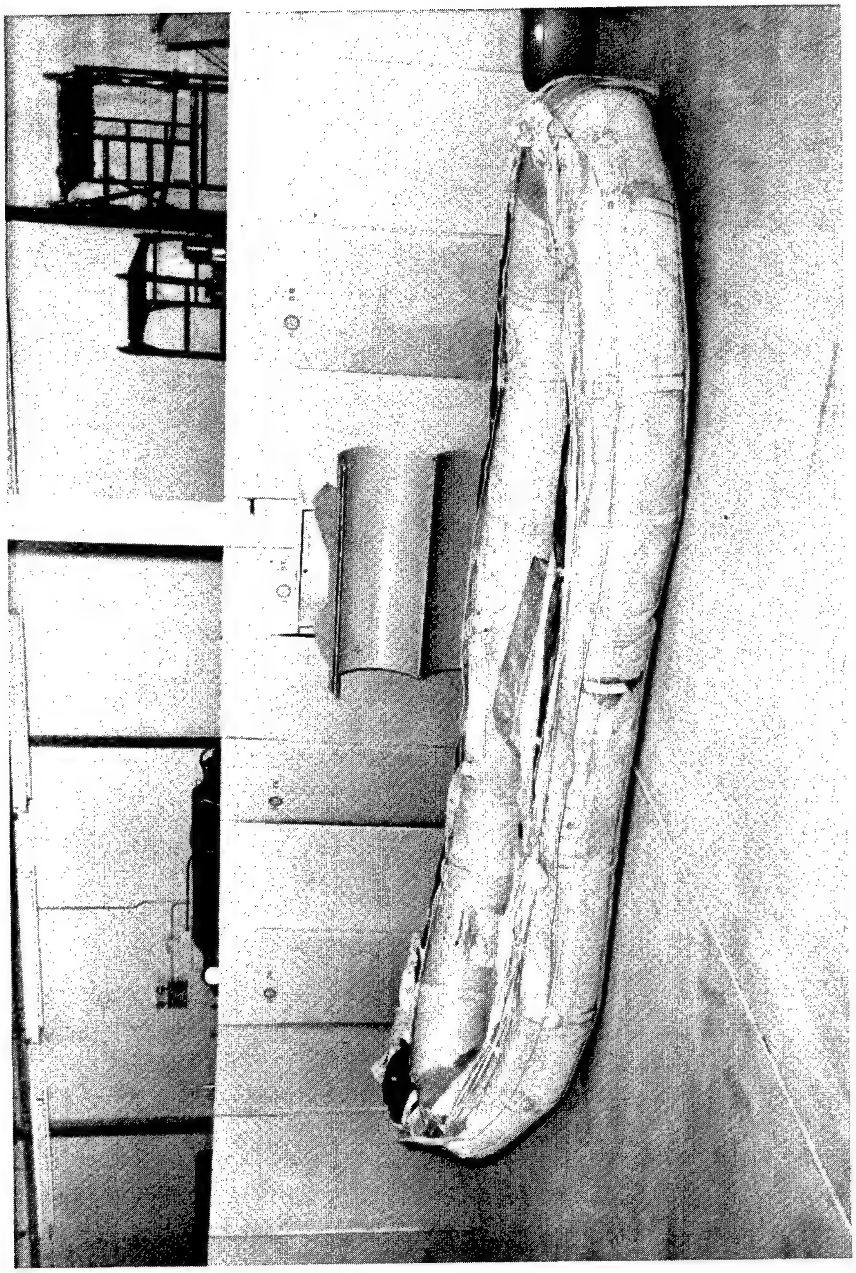


Figure 19. Fully deployed raft.

APPENDIX A

TEST PLAN

AUTOMATIC LIFE RAFT SYSTEM

1. INTRODUCTION

Contract N62269-79-C-0723 was issued by the Naval Air Development Center to The Boeing Company for the development and testing of an automatic life raft deployment system. This document sets forth a plan for fabrication, checkout, testing and demonstration of the life raft system in the various modes of operation.

2. STATEMENT OF WORK

Test and demonstration of the life raft deployment system shall consist of the following tasks:

a. Fabrication of the simulated aircraft test fixture.

b. Fabrication of the remote/manual CO_2 valve.

c. Fabrication of the life raft container pod.

d. Fabrication of the electrical control panel and electrical wiring system.

e. Installation of life raft and CO_2 cylinder.

f. Performance of system checkout.

g. Performance of system operational demonstrations.

h. Photographic coverage.

All raft installation, checkout, testing and operational demonstrations shall be performed in the presence of Boeing and Naval Air Development Center representatives.

3. COMPONENTS FABRICATION

3.1 Test Fixture

A simulated section of the CH-46 aircraft, mounted on a platform shall be fabricated in accordance with drawing SK28607.

3.2 Remote/Manual Valve

A remote/manual valve shall be fabricated in accordance with SK28609. Existing manual valve on CO_2 cylinder (provided by Boeing) shall be removed and replaced with new valve. Some parts from old valve shall be used, such as valve stem, manual release cable assembly, outlet diffuser, etc.

3.3 Life Raft Container Pod

A life raft pod shall be fabricated in accordance with SK28606.

3.4 Electrical Control Panel and Wiring

An electrical control panel shall be fabricated in accordance with SK28663. The panel shall be wired in accordance with wiring diagram shown in Figure 1. A 12 volt battery or 12 volt DC power supply shall be provided. The battery or power supply shall be capable of supplying a minimum of 8 amperes of current for 200 milliseconds for each test. Wires shall be run from the battery to the control box and from the control box to the electrical squib in the life raft CO_2 cylinder valve. All wiring shall be a minimum of No. 20 AWG multi-strand type I insulated copper wire.

Three leads, each consisting of two wires, shall extend from the control box as follows:

a. Control box to life raft valve - 20 feet approx.

b. Control box to water sensor - 2 feet approx.

c. Control box to battery or power supply - length to suit.

Water sensor to be supplied by Boeing.

3.5 Life Raft Assembly Installation

The life raft shall be installed in the pod halves with the lower steel hinge pin installed. Life raft folding procedure shall be developed to make the most efficient use of the space available. The CO_2 cylinder shall be installed parallel to and on the side toward the aircraft test fixture. Manual firing cable shall be fed through a hole in the skin of the pod which shall be added when the optimum cylinder position is established. The two wires to the CO_2 cylinder control valve squib shall be passed through the same hole and attached. The pod, with the raft and cylinder installed, shall be closed up and the upper aluminum hinge pin installed. The raft container pod shall then be attached to the test fixture with 4 1/4 inch bolts.

4. SYSTEM CHECKOUT

4.1 Electrical System

After completing the control box wiring a continuity check shall be made of all circuits with the switches in their various positions. System schematic (Figure 2) shall be referred to.

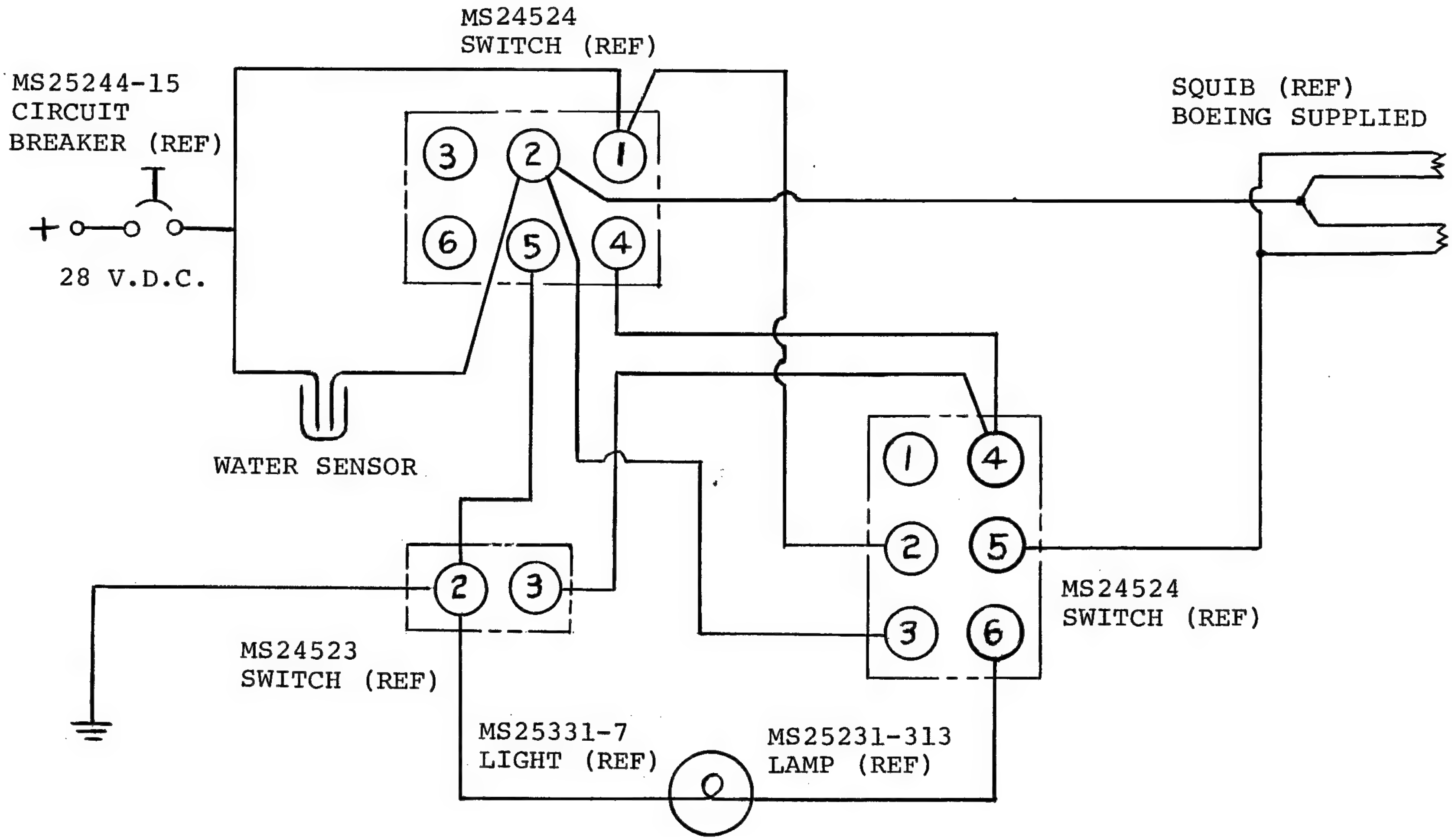


Figure 1. Wiring diagram, life raft deployment system.

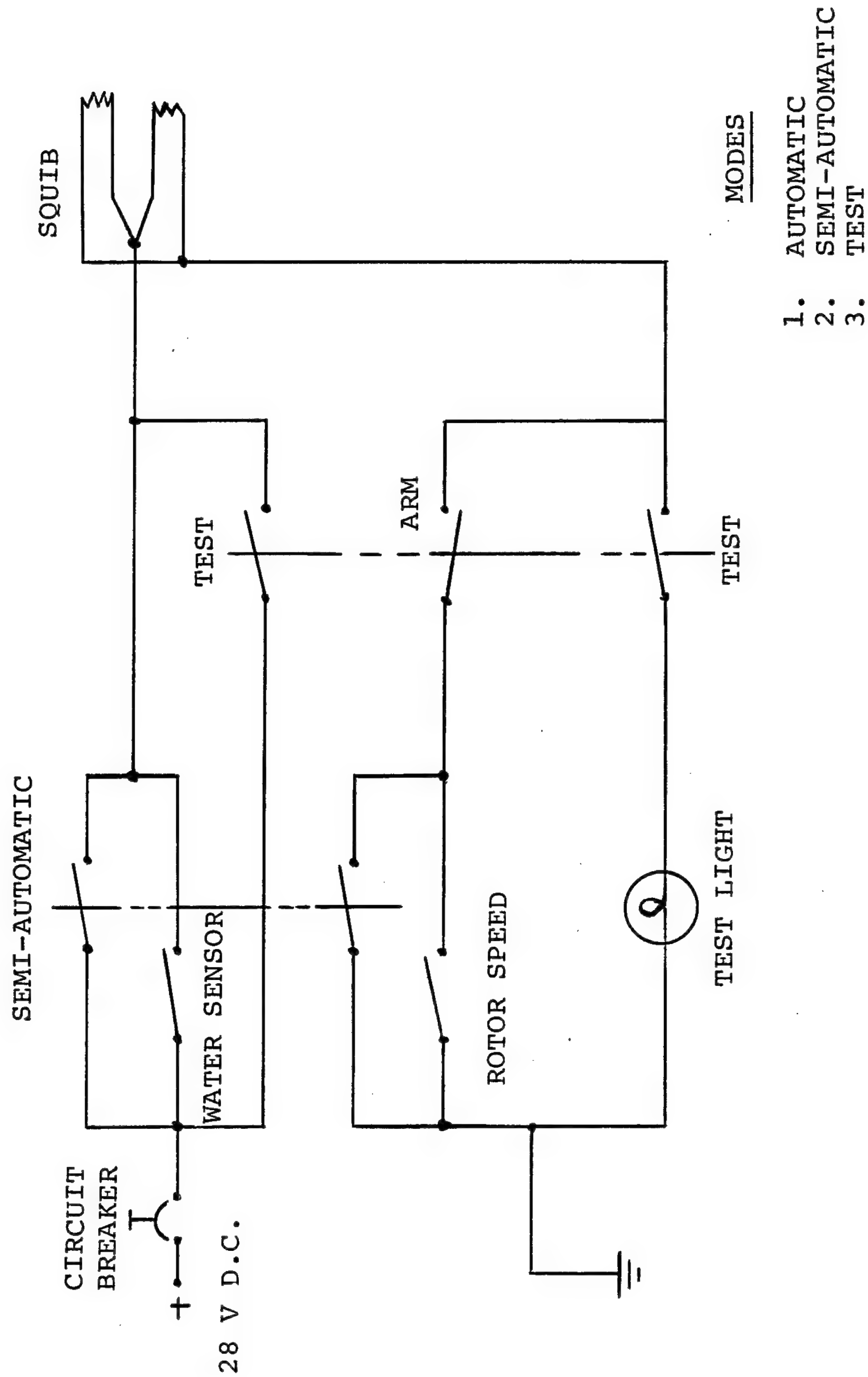


Figure 2. Electrical schematic, life raft deployment system.

4.2 System Test Functional Check

With the battery installed and a spare squib connected to the control box squib leads, the test circuit shall be demonstrated as follows:

a. Verify that arm/test switch is in Off position.

b. Verify that semi-automatic switch is in Off position.

c. Verify that rotor speed switch is in High position.

d. Apply power to system.

e. Place arm/test switch in Test position.

f. Check test light on.

g. Verify that squib did not fire.

h. Return test switch to Off position.

i. Place ammeter in test circuit.

j. Place arm/test switch in Test position and measure current.

k. Verify that current does not exceed 2 amps.

4.3 Automatic Firing Functional Check

The system shall be checked for automatic firing function. With the spare squib remaining attached to the squib leads, the firing system shall be demonstrated as follows:

a. Verify that arm/test switch is in Off position.

b. Verify that semi-automatic switch is in Off position.

c. Verify that rotor speed switch is in High position.

d. Apply power to system.

e. Place arm/test switch in the Arm position.

f. Verify that squib did not fire.

g. Place water in water sensor container.

h. Place rotor speed switch in Stop position.

i. Verify that squib fired.

4.4 Semi-Automatic Firing Functional Check

The system shall be checked for semi-automatic firing function. Remove the water sensor container or disconnect water sensing wiring. The fired squib from the previous test shall be replaced and the firing system shall be demonstrated as follows:

a. Verify that the arm/test switch is in the Off position.

b. Verify that the semi-automatic switch is in the Off position.

c. Verify that the rotor speed switch is in the High position.

d. Apply power to system.

e. Place arm/test switch in Arm position.

f. Verify that squib did not fire.

g. Place semi-automatic switch in On position.

h. Place rotor speed switch in Stop position.

i. Verify that squib fired.

4.5 Remote/Manual Valve Functional Check

The remote/manual valve shall be checked out in both manual and remote modes. With the valve installed on the CO_2 cylinder, the cylinder shall be charged with 4.80 pounds of CO_2. The valve shall be checked in the manual mode by pulling the manual release cable and verifying that the CO_2 in the cylinder is completely discharged.

The remote mode shall be checked after the cylinder is recharged with CO_2 and the electrical squib (Boeing to furnish) is connected. After applying 12 volts to the squib, verify that the squib fired and the CO_2 in the cylinder is completely discharged.

5. SYSTEM OPERATIONAL DEMONSTRATION

After satisfactory completion of the system check, the complete system operational performance shall be demonstrated. A total of three raft deployments shall be demonstrated. One CO_2 cylinder shall be supplied by Boeing. The cylinder will have to be recharged for each demonstration. The cylinder shall be recharged with 4.80 pounds of CO_2.

The demonstration tests to be performed are as follows:

5.1 Semi-Automatic Life Raft Deployment Demonstration

The life raft shall be installed and electrical and manual firing system hooked up as described in paragraph 3.5. The system shall be demonstrated in the semi-automatic mode as follows:

a. Verify that arm/test switch is in Off position.

b. Verify that semi-automatic switch is in Off position.

c. Verify that rotor speed switch is in High position.

d. Apply power to system.

e. Place arm/test switch in Test position.

f. Verify test lamp is lit.

g. Return test switch to Off position.

h. Place arm/test switch in Arm position.

i. Place semi-automatic switch in On position.

j. Place rotor speed switch in Stop position.

k. Verify squib has fired and raft has been deployed.

l. Examine pod and fixture assembly for damage.

5.2 Automatic Life Raft Deployment Demonstration

The life raft shall be deflated and flattened using a vacuum pump or standard vacuum cleaner. The life raft CO_2 cylinder shall be recharged, the firing valve re-set and a new squib installed. Installation of the life raft and cylinder shall be as described in paragraph 3.5. The system shall be demonstrated in the automatic mode as follows:

a. Verify arm/test switch is in Off position.

b. Verify semi-automatic switch is in Off position.

c. Verify rotor speed switch is in High position.

d. Apply power to system.

e. Place arm/test switch in Test position.

f. Verify test lamp is lit.

g. Return test switch to Off position.

h. Place arm/test switch in Arm position.

i. Fill water sensor container with water.

j. Place rotor speed switch in Stop position.

k. Verify squib has fired and raft has been ejected.

l. Examine pod and test fixture for damage.

5.3 Manual Life Raft Deployment Demonstration

The life raft shall be deflated and flattened using a vacuum. A cylinder shall be charged with CO_2 as previously discussed. All wires and initiator shall be removed from the control valve. Installation of the life raft and bottle shall be as described in paragraph 5. The system shall be demonstrated in the manual mode as follows:

a. Grasp bottle release handle from the inner side of the simulated aircraft side and pull until cable pulls free. A lanyard may be attached to the release handle to remove the operator to a safe distance from the test specimen.

b. Verify that cylinder was fired and life raft was ejected.

6. PHOTOGRAPHIC COVERAGE

Still photographs, using black and white film, shall be taken of the test set-up and of the test demonstrations as follows:

a. Three views of the overall test set-up.

b. Two views of the control panel.

c. Two views of the manual control handle.

d. Three views of the test specimen prior to life raft deployment demonstration test.

e. Three views of the test specimen after life raft deployment demonstration test.

f. Close-up views (as necessary) of any change or distortion.

Two sets of 5" x 7" glossy black and white prints shall be supplied of each shot taken.